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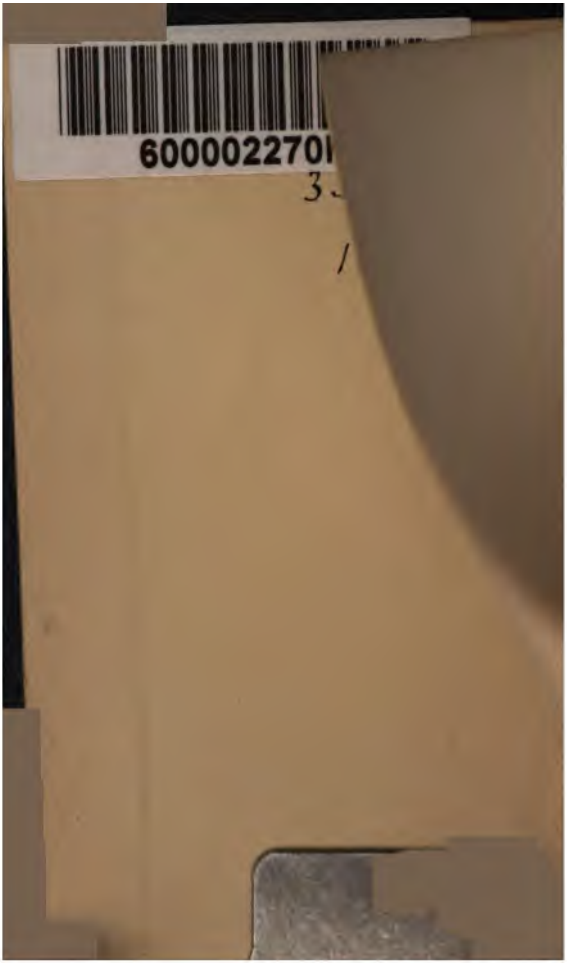
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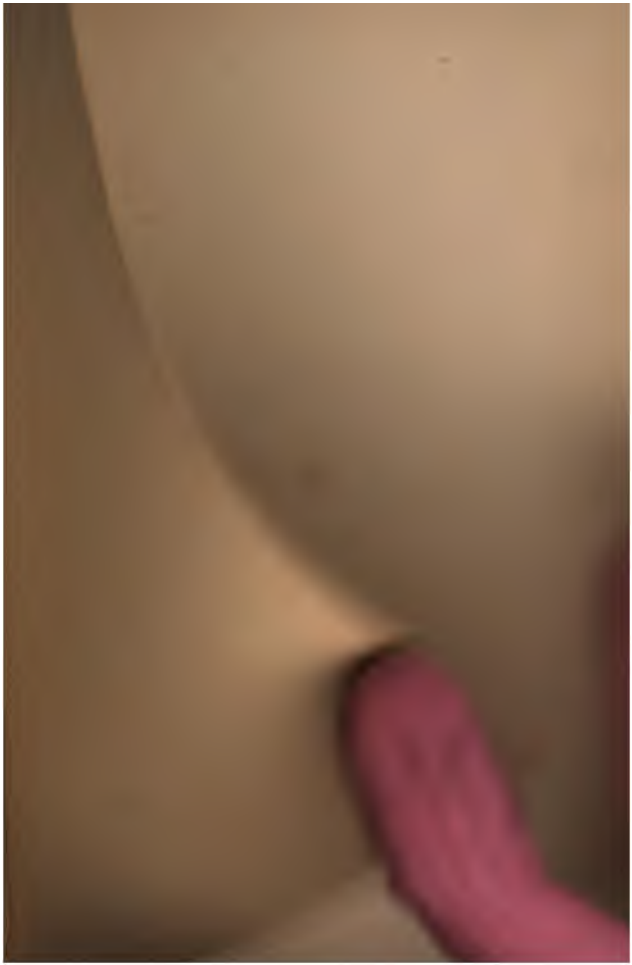

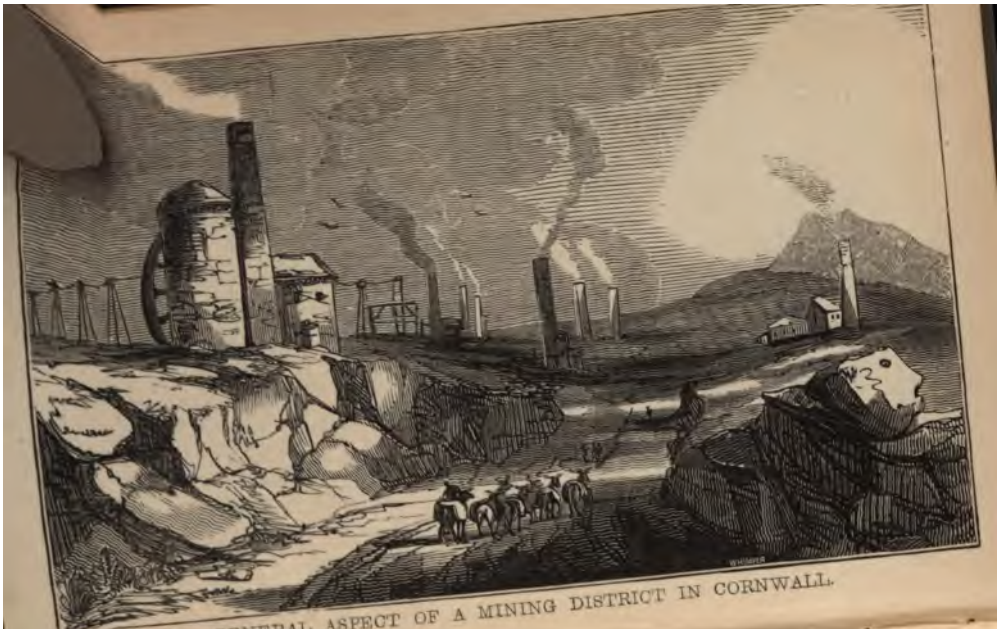

GENERAL ASPECT OF A MINING DISTRICT IN CORNWALL.

MINERALS AND METALS;

THEIR

NATURAL HISTORY

AND

USES IN THE ARTS;

WITH INCIDENTAL ACCOUNTS OF

MINES AND MINING.

PUBLISHED UNDER THE DIRECTION OF THE COMMITTEE OF GENERAL LITERATURE AND EDUCATION, APPOINTED BY THE SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE.

LONDON:
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M.DCCC.XXXV.

105.

limited in number, because they have had those only mentioned to them which are more immediately conducive to our comfort and wants. This, like all other false notions, has to be unlearnt, and increases the difficulty of subsequently acquiring correct knowledge of chemistry and natural philosophy.

As an object for the memory only, every child should be early taught the general names and properties of *all* the simple or elementary substances, whenever he is instructed in the first principles of physical science.

The same objection against a partial enumeration of mineral *compounds* does not exist; because, when the learner has once been told that all these are but combinations of certain simple substances, he easily perceives that their number may be indefinite, or that many may have, as yet, escaped discovery; accordingly, only those are mentioned in the following work, which are important in the arts, or which the learner may frequently see or read of.

The statistical details are, generally, taken from that invaluable work, MAC CULLOCH's *Commercial Dictionary*.

CONTENTS.

CHAPTER I. ELEMENTARY PRINCIPLES.

Pa

Distinction between organized and inorganized matter .....
Division of all material bodies into natural kingdoms .....
Simple Substances, or Elementary Principles.
——————— Imponderable agents .....
——————— brief enumeration of simple Substances
——————— Properties of the Metals .....
——————— Names of ditto .....

CHAPTER II. GRAVITATION, AFFINITY, &c.

Attractions of Gravity and Affinity .....
Examples of Attraction of Affinity .....

CHAPTER III. SPECIFIC GRAVITY.

Explanation of Specific Gravity .....

CHAPTER IV. CRYSTALLIZATION.

Explanation of .....
Primitive Crystals .....
——————— forms of, six in number .....

CHAPTER V. OF THE COMBINATIONS OF THE SIMPLE SUBSTANCES WHICH ARE NOT METALS .....

Sec. 1. *Carbon*. .....
——— Charcoal .....
——— Diamond .....

Page

Sec. 8. Bismuth, properties of 119
——— uses of 120
9. Uranium, properties of, &c. 121
10. Vanadium 122

Chapter VIII.

Sec. 1. Copper, properties of 123
——— alloys of 124
——— manufacture of Brass 124
——— varieties of Brass, as Pinchbeck, Prince Rupert's-metal, &c. 125
——— Bronze, Bell-metal, &c. 126
——— ores of, where found 127
——— Mines of, in Cornwall 128
——— reduction of the Ores 138
——— obtained from Springs 144
——— Blue Vitriol, Verdigris, &c. 145
——— uses of 146
——— ——— in Engraving 147
2. Cadmium 148
3. Cobalt, its properties, &c. 148
——— Zaffre, Smalt, &c. 149
4. Arsenic, properties of, &c. 151
5. Nickel, properties of 154

Chapter IX.

Sec. 1. Iron, properties of 155
—— Alloys and Salts of 159
—— mode of obtaining Green Vitriol 159
—— ——————— Prussian blue 160
—— Meteoric Iron 161
—— Ores of, and where found 162
—— —— reduction of 168
—— different kinds of Iron so obtained 172
—— *further preparation to render* it malleable 174
—— *Steel, mode of making* 178

Page

Sec. 2. Molybdenum 181
3. Tin, properties of, &c. 182
—— alloys of, as Pewter, Solder, Speculum-Metal, &c. 183
—— mode of Tinning Copper Vessels and other Articles 184
—— manufacture of Latten or Tin-Plates 185
—— ores of, where found 191
—— —— reduction of 191
—— Stream Tin-Works 193
—— Mines of, in Cornwall 194
4. Antimony, properties and uses of 196
5. Zinc, properties and uses 198

Chapter X.

Sec. 1. Tellurium 201
2. Manganese 201
3. Titanium 202
4. Chromium 202
5. Columbium 203
6. Rhodium 204
7. Iridium and Osmium 204
8. Cerium 204

Chapter XI.

Sec. 1. Aluminum, history and properties of 205
———— Sapphire 206
———— Oriental Ruby 206
———— Corundum 207
———— Emery, grinding, sorting, and making of Emery Paper 207
———— Turquoise 208
———— Topaz 208
———— Spinelle and Balas Ruby 209
———— Alum, properties and uses of 2

Page
Sec. 2. Thorinum and Yttrium 212
3. Zirconium 212
4. Glucinum 213

Chapter XII.

Sec. 1. Calcium 214
——— Lime, properties of 214
——— ——— Calcareous Spar 216
——— ——— Limestone and Marbles..... 218
——— ——— Chalk 220
——— ——— Fluate of, or Derbyshire Spar.... 222
——— ——— Sulphate of, or Gypsum 222
2. Magnesium, properties of 223
——— Epsom Salts 224
3. Strontium..... 225
4. Baryum 225
5. Lithium 225
6. Potassium 226
——— Potash, Pearlash, &c., how obtained, and uses of 226
——— Nitre, uses of, &c. 228
——— Mica..... 230
——— Feldspar, Granite 231
——— Talc 233
7. Sodium 234
——— common Salt 235
——— Natron 242
——— Glauber Salts 242
——— Borax 243
Ammonia..... 244
——— Sal-ammoniac, uses of..... 244
——— Carbonate of..... 245

Erratum.

Page 214, the Chapter should be XII.

Chapter I.

ELEMENTARY PRINCIPLES.

The first and most essential distinction between all the objects which present themselves to our senses, arises from their being either *organized* or *inorganized:* the former being endowed with that wonderful and incomprehensible energy called *vitality*, by virtue of which they are, *in a certain degree*, exempted from the control of those chemical and mechanical laws, to which all matter is subjected.

It is this primary distinction which has been made the foundation of the two great divisions under which bodies are arranged for the purposes of classification: the first containing the animal and vegetable *kingdoms*, as they were formerly termed; the second, the mineral kingdom *.

* In proportion as we obtain more extended and accurate knowledge of the true constitution of natural bodies, and of their mutual relations, the necessity for increasing the number of kingdoms in classification becomes more apparent: *five* kingdoms are now acknowledged by some naturalists. First, The animal; the second contains those bodies which partake of the nature of the first, and of the following, such as polypes, sponges, madrepores, &c.; third, The vegetable; fourth, The mineral; and the *fifth embraces* the four imponderable agents, heat, light, *electricity, and* magnetism.

All organized matter, and most mineral bodies in nature, are compounded of two or more of a class of substances which, combined in certain proportions, constitute the endless variety of productions of our globe. That is, most natural substances can, by chemical processes, be divided, or *analyzed*, into these elements which are not capable themselves of further division, or, at least, do not appear to be so in the present state of our knowledge.

These are, hence, called *simple substances*, or *elementary principles*: they are, apparently, perfectly *mineral*, or destitute of organization; there are fifty-four as yet known, all possessing the common properties of matter, as weight, impenetrability, &c.

But there are three or four other principles, the true nature of which is not accurately known, it not being certain whether they are distinct, independent, material substances; or only *qualities* of all matter, manifested under particular conditions: these principles are HEAT, LIGHT, ELECTRICITY and MAGNETISM *.

Heat, or *caloric*, pervades all matter, and
idered as essential to its existence:
ntity of heat in matter varies at
es; and when the difference in

sons for suspecting that the two last, if not all
vent effects proceeding from the varied mode
, *more mysterious*, common cause.

this quantity exceeds a certain constant proportion, the matter assumes a new form, and, if *solid* before, becomes *fluid*, or *gaseous*. Thus water, at the average temperature of the air, is a *liquid*, but if a certain quantity of heat be taken from it, the water becomes *solid* ice: or if the quantity of heat in the fluid be increased to a certain point, the water is turned into *steam* or into a *gas*.

The *simple* substances are, therefore, not such, strictly speaking, for heat is contained in them all: they are only termed simple, because they do not admit of being divided, or *decomposed*, by chemical processes, into two material substances: for heat, light, &c., do not appear to possess that essential character of matter, *weight*.

The simple substances are,

OXYGEN, HYDROGEN, CHLORINE, and AZOTE. These, at the average temperature, are gases; and maintain that form in consequence of the heat which exists in them, which is termed *latent*, because it is not perceptible to our senses. Experiment and analogy convince us, however, that these substances could be made to assume a liquid, or even a solid, form, if a certain portion of that heat could be taken from them.

BROMINE and IODINE are either gaseous, liquid, or solid, according to the temperature.

FLUORINE has not yet been obtained in a separat

state; and is only known to be a distinct substance from the qualities of the compounds it forms with other matter.

CARBON, BORON, SILICON, PHOSPHORUS, SULPHUR, and SELENIUM, are solids; but differ from the remaining forty-one, which are also solid, in being non-conductors of electricity.

Forty-one are *Metals*, which are distinguished by the following qualities.

1. They are *better conductors of heat and electricity* than most other substances: a bar of metal, heated at one end, will sooner become hot at the other, than a bar of equal size made of any substance not a metal. That is, if an additional quantity of heat be imparted to one part of a mass of metal, this heat will diffuse itself, by *conduction*, sooner through the whole mass, than the same quantity of heat would do through any other substance. The metals possess a similar property with regard to the electric fluid: but they differ among themselves greatly in the degree in which they have both of these qualities.

2. Metals are *not soluble* in water.

3. They *all* unite with Oxygen, and perhaps all with Chlorine, though with different degrees of readiness; when thus combined, they form what are termed *Oxides* and *Chlorides*; and it is in the state *of oxides that they* are generally found in nature. *When the metals* do occur nearly pure, or free

from other substances, they are termed *native*, in chemical and geological language.

4. The *Oxides* of metals unite with different *acids*, and form peculiar compounds called *salts:* in which state they also occur naturally in abundance.

The four preceding qualities are common to all the metals, and, collectively, to no other bodies; they may be called their *essential characteristics;* while the following properties belong only to some of them, and to these in very different degrees.

It is these secondary qualities, however, which render the metals possessing them the most valuable to man of all natural productions, next to those serving him for food or clothing. And, indeed, without the assistance of these metals, man could only avail himself to an extremely limited extent, of these requisites to his existence.

5. The metals are *opaque*, or do not admit of light passing through them. This property must, however, be understood as *relative:* it is probable that *all* bodies would allow some light to pass through them, if they could be reduced to a sufficient thinness, but the metals less than others.

6. FUSIBILITY, or the power of being rendered *fluid* by a heat attainable by artificial means; and of becoming solid again on *cooling*, or on parting with that additional heat.

It is this property which enables us to separate

some metals from the other mineral substances with which they are commonly found mixed, and which are usually not fusible in any ordinary heat; and it is this property which enables us to form instruments, tools, &c. from them when so obtained.

7. MALLEABILITY, or the capability of being *hammered* into various forms without breaking, as stones or earths would do if so treated: in many metals this quality is increased by heat.

8. DUCTILITY, or the capability of being *drawn out* without breaking: this, and the former quality, are the results of the TENACITY of the metals, which allows of their component particles being separated to a certain distance, without destroying their adhesion.

If we attempt to lengthen a stone, by pulling it, it either absolutely resists all our efforts, or else breaks: many metals, on the contrary, can be so drawn out; and some, as will hereafter be mentioned, in a most wonderful degree.

9. Metals are *elastic* in different degrees, *hard*, *heavy*, and possess a peculiar lustre, smell, and taste, called *metallic*. But these qualities are common to many other substances, and are, therefore, not *characteristic* of the metals.

The names of the metals are,

PLATINUM, GOLD, Tungsten, *Mercury*.

LEAD, PALLADIUM, SILVER, BISMUTH, Uranium, *Vanadium*.

COPPER, CADMIUM, Cobalt, Arsenic, *Nickel.*

IRON, Molybdenum, TIN, *Antimony*, ZINC.

Tellurium, Manganese, Titanium, Chromium, Columbium, Rhodium, Iridium, Osmium, Cerium.

Aluminum, Thorinum, Yttrium, Zirconium, Glucinum.

Calcium, Magnesium, Strontium, Baryum, Lithium, Potassium, Sodium.

Those metals the names of which, are printed in capitals, are more or less malleable. In the above list, the metals are arranged according to their weight, and to certain chemical qualities; if classed according to their *utility* to man, in an economic point of view, they would perhaps stand thus:

Iron, Copper, Tin, Lead, Silver, Gold, Mercury, Zinc, Platinum, Palladium, Nickel, Cobalt, Bismuth, Antimony, Arsenic, Chromium, Manganese.

All the rest, as metals, are unemployed and comparatively unknown: though the metals, Aluminum, Calcium, Magnesium, Potassium, and Sodium, in the state of compounds with oxygen, &c., are among the most important and most extensively diffused of all natural substances, contributing with Silicon, &c., to form the well-known earths and alkalies, Clay, Lime, Magnesia, Potash, and Soda; as will be hereafter more fully explained.

Chapter II.

OF GRAVITATION, AFFINITY, &c.

All matter is subjected to two great laws :—*First*, The Attraction of Gravity, by which every particle mutually attracts every other; it is this attraction which causes the *weight* of matter; all bodies are attracted by the earth, in proportion to their size, or in proportion to the quantity of *matter* they contain; and the planets are kept in their orbits by the mutual attraction of gravity between them and the sun.

Secondly, Besides the attraction of gravity, there is another, equally mysterious and wonderful, which the particles of matter exert among each other in different degrees, and by virtue of which they unite, in *certain definite proportions only*, to constitute the various substances of the earth. This attraction is called Affinity.

Affinity, unlike gravity, only acts when two bodies are in close contact; it is a *chemical* and not a *mechanical* law. When two simple substances, which have affinity for each other, are placed in situations favourable to their union, they combine so intimately as to change their chemical and, most *commonly, their sensible* qualities also.

The affinity of any one of the simple substances is not equally great for all the others; it is frequently so strong for one, in preference to the others, that the two are always found combined in nature, and can only be separated with difficulty.

The whole science of practical chemistry is founded, and depends, on this property of affinity: we possess no power of separating two, or more, substances which are *chemically* united, but by adding to the compound another, which has a greater affinity for one of those contained in the compound, than they have for each other: the consequence is, that a new union takes place between the newly added substance and one, or more, of the original substances; and the remaining one is left *free* or in its original state.

As all the processes for *reducing* the metals from their *ores* are of this nature, in order to render those processes more intelligible, a few examples of chemical affinities will be given to illustrate the remarkable changes produced in the chemical and sensible properties of substances by their union.

Oxygen is a colourless gas, in *appearance* like common air; it will not burn, but, by its presence, enables other substances to burn with great violence. Hydrogen gas is, in appearance, like oxygen; but, while no body can burn if immersed in it, the gas *itself burns, if* set on fire, with a pale flame, but

giving out intense heat. If these two dry airs, or gases, be mixed in a certain proportion, and then set on fire, they burn with a report, instantly disappear, and form a liquid—*water:* and the weight of the water, thus produced, is precisely equal to that of the two gases from which it proceeds.

Certain metals have a greater affinity for oxygen than hydrogen has; if, when pure, they be immersed in water, this liquid is *decomposed,* the hydrogen is disengaged, and the oxygen unites with the metal, and forms an oxide of it.

The affinity of the last twelve metals, Aluminum, Calcium, Potassium, Sodium, &c., for oxygen, is so strong, that these metals are never found naturally pure, and are only obtained in that state by a very peculiar process; the *oxides* of them, which are abundant, are the pure *earths,* alumina, lime, &c., and the *alkalies,* Potash and Soda.

The process of *cupellation,* hereafter described (see Lead), is founded on the greater affinity of lead for oxygen than of silver for that gas.

Solution, in water or in other liquids, is the effect of affinity. If pounded chalk be stirred up in water, the particles of chalk are *diffused* through, but not *dissolved* in, the water; there is only a *mechanical* and not a *chemical* union; and, after a

the chalk sinks to the bottom of the vessel

unchanged, leaving the water as pure and tasteless as before. But if common salt or sugar be put into water, they dissolve, and disappear; the water acquires new properties of taste, &c.; and the two component parts can only be re-obtained by a new chemical action.

Sulphuric acid is a compound of oxygen and sulphur; and is an extremely corrosive liquid: *Strontia* is an oxide of the metal Strontium, and is an earth: these two compounds form, together, a salt called *Sulphate* of *Strontia.* Carbonic acid is a compound of oxygen and carbon, and potash has been mentioned as a metallic oxide; the salt, *carbonate of potash,* is produced by the union of these two compounds.

Now if certain weights of these two salts be dissolved in water, and mixed together, the following curious result is produced: the carbonic acid, having a stronger affinity for the Strontia than it has for the potash, quits this alkali and unites with the earth, forming a new salt, *Carbonate of Strontia:* while, for similar reasons, the sulphuric acid, disengaged from the Strontia, unites with the potash, which is left free, and forms *sulphate of potash.*

As examples of the striking change in the properties of substances, produced by chemical combinations of them, the following may be mentioned in addition to the foregoing.

Chlorine is a gas resembling oxygen in some of its properties, as in the power of supporting the *combustion*, or the burning, of other bodies, and in uniting with metals, forming what are called *chlorides*, analogous to oxides. Common salt is a combination of chlorine with sodium, or is a *chloride of sodium*.

Chlorine, combined with hydrogen, forms a powerfully corrosive acid, called *hydrochloric acid*, while oxygen, combined with hydrogen, only produces water.

Azote, another gas, is remarkable for being fatal to organic life in every form, and equally so to combustion. A living animal, if put into this gas, dies in a few minutes; and a lighted taper is instantaneously extinguished, if plunged into a vessel filled with the gas.

Chloride of Azote, a combination of these two gases, is one of the most formidably explosive compounds known; far exceeding gunpowder in this respect.

Common, or atmospheric air, is a union of oxygen and azote; the latter fatal gas constituting four-fifths of this atmosphere, so necessary to the existence of all life, vegetable or animal.

Chapter III.

OF SPECIFIC GRAVITY.

It will be necessary, before proceeding further, to explain what is meant by *specific gravity*, since this is an indispensable term, constantly occurring in all books treating of natural substances, and should, therefore, be well understood.

Different pieces of the same substance, as iron for example, will be of different *weights* according to their size: a small piece would weigh much less than a large one of some other substance, which would be really lighter, if the two were of precisely the same magnitude. It is very important, in all scientific investigations of natural substances, to know what their *relative weights* would be, if they were of the same magnitude, or their relative weight compared with some common standard.

Let a piece of iron, a piece of gold, and a piece of cork, of precisely the same size, be compared with an equal piece of the common standard, the iron will be found to weigh 78, the gold 192, the cork only 2, supposing the standard to weigh 10. *These numbers* are the specific gravities of these

substances; because, if equal pieces of them of any other size were taken, their *relative* weights would be the same, though their absolute weights would be less or greater than those of the first pieces, according as they were smaller or larger than them.

Now it obviously would be troublesome in all cases, and in some impossible, to reduce a new substance to precisely the same size with any other, for the purpose of comparing their weights: the fundamental laws of matter obviate the necessity for this proceeding, in the following manner.

If a piece of any substance, whatever may be its form, be immersed in a fluid, as water, it will displace a quantity of this fluid exactly equal to itself in bulk. The substance when so immersed is supported, in some measure, by the water pressing upward on its under-side; and it consequently loses some of its weight, the difference, or this loss, being precisely that of the bulk of water displaced by the body.

Hence, if water be assumed as the *standard*, by weighing a body first in the air*, and then again

* The air is a fluid just as much as water, therefore the weight of all bodies in the air is really *less* than their absolute weight, by that of the volume of air which they displace: this, however, is so *trifling, compared to their own* weight, that it is commonly unnoticed, *when solids are treated of*; strictly, the absolute weight of a *body can only be ascertained by* weighing it in a vacuum, or a space

when immersed in water, the difference of the two weights is the weight of a body of water precisely equal in bulk to the body; consequently the *relative weights* of the two, or the specific gravity of the body is ascertained, whatever may be its real or absolute weight as depending on its size.

The kind of *scales* by which bodies are weighed in water, to obtain their specific gravity, is called a *hydrostatic balance;* and is constructed with apparatus proper for the purpose, but it is not necessary to enter into any particular description of it in this work.

Some bodies weigh less than an equal bulk of water, but *all* the *durable* metals are heavier. Distilled or pure water, being taken as a standard, or as weighing 10, pure platinum, the heaviest, weighs 195, or 19½ times heavier than an equal bulk of water; and arsenic, which is perhaps the lightest, weighs 57 or rather more than 5½ times the same bulk of water.

deprived of air by means of an air-pump. The specific gravity of *gases*, and other bodies which are nearly of the same density as common air, is obtained by a more complicated process, though in principle the same: in such cases common air and not water is taken as the standard.

Chapter IV.

ON CRYSTALLIZATION.

There are many mineral, or inorganic substances, which assume certain regular forms when becoming solid from a fluid state, or when, after being dissolved in a fluid, this fluid is *evaporated*, or dried up, so as to restore the substance to its separate solid form. This property is termed *crystallizing*, and the regular figures are termed *crystals*.

The cause of a body's possessing the power of crystallizing is not known, but it is supposed to be *connected* with the form of the particles, or *molecules*, as they are called, of which it is composed.

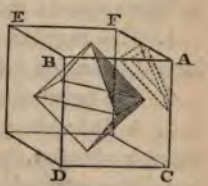
If a piece of *calcareous spar*, or carbonate of lime of particular kind, be broken by a gentle blow into several small pieces, and this repeatedly; these pieces will *always* be found of the same form, and their sides perfectly smooth and regular; the form is what geometricians call a *rhomboid*, or a solid of six faces, the two opposite ones, taken in three pairs, being parallel and equal four-sided figures, but the sides of these figures not being perpendicular to each other, as those of a *square* are.

If the mineral were broken violently, or crushed, *the fragments which* were not these regular rhom-

boids, would be found to be irregular and rough, and no other smooth regular figure but the rhomboid could be obtained from it.

Many other minerals, if treated in the same way, will present the same phenomenon, but the figure into which they divide varies.

Several, however, admit of being divided into more than one regular geometrical figure, but in this case it will, almost always, be found, that these different figures are such, that one might be produced from the others, by either cutting away the angles according to regular laws, or by supposing equal additions made on the faces of the one figure, which would convert it into the others.



To explain this, let the cube A B C D E F be one of the forms into which a mineral divides easily by breaking, or *cleaving*, it will be found that the same mineral can also be mechanically divided into, or will occasionally be found crystallized in, the other form represented within the cube, called an *octohedron* (having eight faces); and this figure can be produced from the cube by cutting away the solid angles, regularly, by small three-sided slices, as is shown by the dotted lines on the angle A.

Again, if a succession of such triangular slices, of equal thickness, but diminishing regularly in size, be supposed added on each of the eight faces of the octohedron, the cube would be reproduced; or if the six angles of the octohedron be imagined to be cut away, by slices parallel to the faces of the original cube, another smaller cube would be obtained.

When a mineral yields crystals of more than one form, one of these, and generally that from which the others can be most readily obtained by geometrical treatment of the kind above explained, is called the *primitive crystal*; and the others are *considered* as modifications of it produced by the addition, or subtraction, of molecular particles of a constant form.

There are six primitive forms of crystals.

1. The regular tetrahedron, having *four* equilateral triangles for its faces.

2. The regular cube of *six* squares for its faces.

3. A dodecahedron, or solid of *twelve* faces, each being a *rhombus*.

4. The octohedron, having *eight* triangles for its faces.

5. A six-sided prism.

6. A parallelopiped, or a solid of six faces, each two of which are parallel and equal, as a *cube*, a *rhomboid*, &c.

From these six, every variety of form of crystal

which occurs in nature, may be *supposed* to be produced by cutting away its angles or edges in various manners; or by additions supposed to be made on its faces, in the manner above explained.

It must not be imagined that every mineral crystallizes naturally in, or can be cut into, all the forms, which might be deduced from its primitive form; but it never occurs that the same mineral is found assuming a form, which cannot be shown on these principles to be related to its primitive, in which primitive it either is occasionally found, or to which the other forms in which it occurs may not be reduced.

Carbonate of lime (the earth lime combined with carbonic acid,) for example, is found crystallized naturally in five hundred varieties of form, all of which can be shown to be reducible to the rhomboid before mentioned; and none of them are connected with, or can be referred to, a cube.

Fluor-spar, the metal Calcium combined with Fluorine, has the regular octohedron for its primary crystal, and the seventy various crystals in which it is found are all reducible to this; among them, accordingly, the cube and the dodecahedron occur, because both of these are referrible to the octohedron: the former in the manner before explained, and the latter is obtainable by adding a four-sided *pyramid on* each face of the cube, as is shown in

this figure. One crystal of fluoride of calcium is found, having no less than three hundred and twenty-two planes, obviously a cube with its twelve edges and eight angles cut away, or more properly speaking, left unfinished as it were, in regular forms, like a piece of glass cut artificially.

Blende, an ore of zinc composed of sulphur and the metal, (see ZINC,) can be easily cut by a knife, or *cleaved*, as it is termed, into its primary crystal, which is a regular octohedron, into a regular tetrahedron, and into a rhomboid of a particular form.

Crystals are only procured artificially from a substance in solution or in fusion; and perfect tranquillity is necessary to allow of their being formed in such circumstances. Hence, when a body is found crystallized naturally, it is considered to have assumed that form by either cooling gradually from a state of fusion by heat, or to have been deposited from a solution. The former appears in Nature to have been the most abundant source of crystallization.

There are but few minerals which can be made to *crystallize* artificially, in comparison with the number *which are found* naturally to assume that state.

Chapter V.

OF THE COMBINATIONS OF THE SIMPLE SUBSTANCES WHICH ARE NOT METALS.

We shall now proceed to mention some of the principal mineral compounds formed from the simple elements which have been enumerated, confining our notice to those which are interesting to the general reader from their importance to man, or from their particular uses.

The combinations of two or more *gases* will not be further noticed, as being foreign to the object of this work. The two most important, atmospheric air and water, have been already mentioned; without these, aided by heat, light, and electricity, no organized beings could exist, as far as we are able to comprehend what is essential to that existence; for it must always be borne in mind that it is through ignorance alone, that we presume to estimate the relative importance of any created thing. It is not because the immediate uses or effects of any elementary principles *appear* more extended and more obvious, than those of others, that they are really so; reason and analogy should induce us to believe that every agency, even the most hidden or the least frequent, is equally *essential to* the well-being of the whole.

The union of oxygen and chlorine with other bodies, is frequently attended with the production of heat and light, giving rise to what is termed *combustion*, or *burning*: but combustion, in scientific language, is considered as taking place, even when no heat or light is manifested to our senses. The gradual oxidation of metals, called in familiar language, *rusting*, or *tarnishing*, is only a modification of the same phenomenon as the combustion of the metals when heated to a certain point, and which, if taking place in a vessel filled with oxygen or chlorine, is productive of an intense heat and brilliant light.

There is an extensive and most important class of bodies called *acids*, produced by the union of oxygen, chlorine, hydrogen, and some other simple substances, with one another; which possess the common property of readily uniting with a third, and forming a compound called a *salt*. Most acids, especially those having oxygen for the acidifying principle, are *sour*, and turn vegetable blue colours red; but neither of these properties are essential to an acid: their proper characteristic is great facility of chemical combination.

Another less numerous, but perhaps equally important class of compounds, of two or more *simple substances*, are the *alkalies*, which possess properties the direct opposites of those of the acids.

they turn vegetable blues green, and neutralize the effects of acids, when combined with them. It is the acids and alkalies that are the origin of most of the vegetable principles which impart flavour to the products of that natural kingdom, and fit them for articles of food, medicine, &c.

Of the six simple solid substances, mentioned in p. 4, as non-conductors of electricity, we shall describe four, which are the most generally diffused, and the most interesting.

Section 1. CARBON.

CARBON is the essential constituent principle of all vegetable matter, and therefore, indirectly, of most animal matter also. We do not know it in its perfectly simple state, though it is obtained nearly pure in charcoal; and what is surprising, the diamond appears to be this element in a still purer form. If the best charcoal be burnt in oxygen, carbonic acid gas is formed, the weight of which is nearly equal to that of the charcoal and the oxygen; there being a small residuum of earthy ashes left after the combustion, arising from the foreign matters contained in the wood of the plant from which the charcoal was procured: but if, in like manner, a diamond be burnt in oxygen, carbonic acid is equally the result; though, in this case, it

is not only precisely equal in weight to the two elements, but there is no residuum whatever.

Why it is, or how it is, that the same elementary substance can, with little or no addition, form two such dissimilar bodies as charcoal and diamond, the former a black, soft, brittle mass, the latter the hardest and clearest body in nature, is a mystery which we cannot solve, and which, like every other natural phenomenon, should inspire us with awe and with humility.

Diamonds are chiefly found in India, in the provinces of Golconda, Visapour, Bengal, &c., in the sands of rivulets. The common mode of obtaining them is to turn the course of the stream, and to wash, sift, and pick the sand, to separate the precious stones.

There are diamond mines, or *workings*, as they should rather be called, in South America, and other places.

The primitive crystal of the diamond is an octohedron, the edges of which are often slightly curved. It is by means of this natural edge only, that glass can be *cut*; all broken or artificially-formed edges, will only scratch and tear that substance. Glaziers' diamonds are made by setting a small piece of natural crystal in a socket, so that the flat side of this socket, which is to be held against the rule, may *be parallel to the plane* of the curved edge; this

causes the edge to cut the glass with a clean and even line.

Diamonds are cut and polished by being rubbed against a flat steel wheel, made to revolve rapidly, diamond-powder, that is diamonds pounded fine, mixed up with some oil, being spread on the surface. When the upper part is ground down to a flat face, large in proportion to the others, the stone is termed a *brilliant;* the face is called the *table.* When the stone is cut with numerous small faces, all forming a pointed pyramid, it is termed a *rose* diamond.

Diamonds are found of every shade of colour, from nearly black to the most perfect transparency; it is the last only which are esteemed, and when a large one is discovered, of a perfect *water*, as it is called, free from flaws and admitting of being well cut, its value, from its rarity, is enormous.

The largest diamond known, belonged to the late Emperor of Brazil; it is still uncut, and weighs 1680 carats*, or 11 ounces 96 grains. This stone, according to the table of rates used in valuing jewels, would be worth 5,645,000*l.*; this is, of course, an imaginary value; 600,000*l.* never was even *offered* for it.

* Jewellers weigh diamonds by a particular scale; one grain is divided into 16 *parts;* and 4 grains make one carat. Five *diamond grains* are equal to four grains troy weight. The carat is *therefore* 3·2 troy grains.

The diamond among the Russian crown jewels, valued by the same scale, would amount to 4,804,000*l.*, yet we know that it was bought for 150,000*l.*

The Pitt, or Regent diamond, now the property of the French monarch, weighs nearly one ounce, and was purchased for 100,000*l.*

The demand for diamonds of the average size is so steady, that there is a regular market price for them, which has hardly ever varied. *Brilliants* of *two* carats in weight, fetch from 27*l.* to 30*l.* Brilliants of *five* carats are far from common, and are worth from 180*l.* to 200*l.*

The uses of the diamond, besides being universally sought after as a beautiful ornament, are, to serve as sockets for the pivots of the principal wheels in clocks and watches; to form lenses for microscopes; for the use of glaziers, as beforementioned, &c.

But it is for the purpose of grinding and cutting other hard substances, that the greatest demand for diamonds exists; all those of a bad colour, or form, are reduced to powder, by the help of which all precious stones are cut and polished, as well as rock-crystal, agates, onyxes, cameos, intaglios, and crests and cyphers for seals, in carnelian, bloodstone, &c. &c.

It is not only owing to its clearness, and to the

number of *facets* of the *brilliant*, that its resplendence is owing. The diamond possesses optical properties, which are the cause of this; it *refracts* the rays of light more unequally than glass or most other transparent bodies; hence the different coloured rays are more distinct; and succeeding each other rapidly, as the stone is moved, they give that appearance of brilliance and variety so peculiarly striking in this gem.

Plumbago, or *Black-lead*, is a compound of carbon, with a small portion of iron, and some earthy matters: it owes its common name to its metallic lead-like lustre and colour, but that metal does not at all enter into its composition. (See IRON.)

Naphtha, or mineral oil, is a liquid, nearly colourless, lighter than water; composed of carbon, with about 13 per cent of hydrogen. It flows from out of the ground in certain countries, particularly in the neighbourhood of the Caspian sea. Naphtha is burnt as oil in some kinds of lamps; the city of Genoa is lighted by naphtha, obtained from a spring near Amiano in Parma. It is also used medicinally, and is nearly allied to

Petroleum, another mineral oil, rather thicker than tar, and of a reddish-brown colour. It occurs in most countries where coal is found, but the largest quantity is obtained from the Birman empire, where *there are 500* wells excavated to receive the petro-

leum which flows into them from over large beds of coal; in this way more than 400,000 hogsheads are obtained annually. In the east it is burnt as oil, and when mixed with other matters serves as fuel. Petroleum is so abundant in Persia that one well alone, among numerous others in the neighbourhood of Badku, will yield from 1000 to 1500 lbs. per diem.

In the island of Zante petroleum is obtained from the same spot, and in the same manner, as it was in the time of Herodotus.

Bitumen, or Mineral Pitch, is a soft solid substance of a dark-brownish colour; there are three varieties of it found in France, England, Germany, and other countries. That called *Asphaltum* floats in masses on the Dead Sea in Judæa. In the island of Trinidad, there is a lake of this substance three miles in circumference, and of unknown depth. Bitumen and Asphaltum are used, in some countries, as cement, and in the preparation of certain varnishes, and are also burnt as a fuel. The ancient Egyptians used Asphaltum in embalming the dead. Bitumen is similar in its component parts to Naphtha and Petroleum, but contains a la ture of foreign matters.

its varieties is a compound of carbon, d oxygen, with earthy matters in ortions. It is of vegetable origin,

having been produced by the gradual decay of trees and plants which were carried down the rivers of the antediluvian world, and deposited at the bottom of the sea, or of inland lakes, along with purely mineral substances, which owe their presence there to the same cause. Any further notice of this important substance, would be misplaced in this work, it having been mentioned only as connected with the following.—

Jet is a species of coal, in which all traces of its vegetable origin are generally obliterated, or which has been more completely mineralized than the common coals. It is manufactured into ornaments for mourning dresses in France and Germany, as it admits of being turned in a lathe, and of receiving a high polish; but it is soft and brittle: when not fine enough for this purpose, it is used as fuel.

Amber is found in similar localities to coal and jet; it is supposed to be a vegetable resin fossilized. It is brittle, easily cut with a knife, of various shades of yellow, and semi-transparent; insects of different kinds are frequently found enclosed in it, which circumstance may be easily accounted for on the supposition of its vegetable origin.

There are regular mines of amber near the coast of Prussia. It is met with in a bed of *lignite*, or imperfectly-formed coal, under a stratum of sand *about twenty* feet thick. The amber is found im-

pregnating parts of the trees, and hanging from the trunks and branches, in the form of stalactites. These mines are worked to a depth of a hundred feet.

In the royal cabinet of Berlin there is a mass of amber, which was discovered in Lithuania, the largest ever found, weighing eighteen pounds.

Amber is one of the most electric substances known; its principal use is for making beads, ornaments, and mouth-pieces to tobacco-pipes. It is, or was, also used in medicine.

All the compounds into which carbon enters largely, are highly inflammable. From the foregoing account of the principal of them, it appears that this simple substance, forming, as it does, the basis of the solid or woody parts of all plants, is essentially connected with the vegetable kingdom; the diamond is perhaps the only instance of carbon being found solely as a mineral, and in that form it is also the purest.

Section 2. Sulphur.

Sulphur is a generally-diffused element, and usually found in volcanic districts. It is of different shades of yellow, and occurs either in masses, or crystallized in the form of an elongated octohedron *and its* derivatives, in veins, in granite and other *rocks, or else in beds* in similar situations.

From its great volatility it is sublimed by means of the heat of neighbouring volcanoes, and is again condensed in a pure state in the clefts and chinks of lava, and other rocks in such localities.

A great part of that used in Europe is derived from the Solfatara, near Naples, a sunken plain surrounded by rocks, and supposed to be the crater of a volcano not now in activity. From the numerous fissures and cavities of this spot, sulphureous, muriatic, and aqueous vapours are continually evolved. Considerable quantities are also procured from Sicily.

But to meet the demand, sulphur is also manufactured here by roasting pyrites (see COPPER); it is melted and cast in cylindrical moulds, and hence derives the common name of *roll* sulphur: this sulphur is not so pure as that imported from Italy and Sicily. The principal consumption of sulphur is in the manufacture of gunpowder, and in making sulphuric acid; it is also used in medicine and surgery, and in many other arts, and, though last, not least, in the manufacture of matches.

In 1831, 289,421 cwt. were imported into this country, 265,000 cwt. of which came from Italy and Sicily. The price varies from about 13*l.* to 20*l.* a ton.

Sulphur fuses, at a low temperature, into a brownish liquid, and is hence used in taking casts of *coins and* medals; for when cold it is hard, of

bright colour, and, being perfectly insoluble in water, is not affected by the atmosphere. At a higher temperature, it burns with a pale, blue, lambent flame, emitting suffocating fumes of sulphurous acid gas.

Sulphur is found combined with several metals, forming *sulphurets*, constituting the most important ores of some, as of lead, zinc, &c.

Section 3. Phosphorus.

Phosphorus is never found pure in nature; and is only obtainable from organic matter, by elaborate chemical processes. It is a soft, waxy, semi-transparent substance, possessing so strong an affinity for oxygen, that it burns spontaneously in the air, giving out a dense white smoke and a pale yellow flame; it is hence a dangerous substance in the hands of incautious persons, for when once ignited, water will not extinguish it, and it sticks so tenaciously to the clothes or flesh, and gives out so great a heat, as to be productive of serious injuries. It must be kept in bottles quite filled with water, and closely corked.

Phosphorus is apparently a most important agent in nature, and exists in most animal matters. The *bones of* all warm-blooded animals consist, in great measure, *of phosphate of lime*, a salt composed of that

earth and phosphoric acid. The luminous appearance of the sea at night, when disturbed by a ship moving through it, is owing to the presence of myriads of small marine animals, of various kinds, which possess the power of emitting the peculiar light called, from its supposed origin, *phosphorescent*. The light of the glow-worm, the lantern-fly, and other insects, is attributed to the same cause; and every one knows that most fish, and molluscous, or testaceous animals, when in a state of decomposition, give out the same kind of light.

Phosphorus only enters into the composition of a few minerals, and these are not of any general interest.

Section 4. Silicon.

This simple element is the most abundantly diffused substance in nature. The earth, *silex*, is an *oxide of Silicon*, and constitutes the greater part of all the rocks of which the crust of the globe is composed. Flint, Quartz, or Rock-crystal, &c., are *hydrates of Silicon*, or Silex with some *water of crystallization*; that is water, as far as its constituent elements are concerned, but not obtainable from the mass in a separate state. These three compounds form alone either whole mountain-ranges, or, *entering into* composition with other minerals,

contribute to the formation of Granite, Gneiss, and other rocks, of which the loftiest and most extensive mountain-chains are chiefly composed.

Quartz, is the scientific name for *flint* or *rock-crystal*, and is found in every variety of form, though varying but little in its composition. It usually occurs, when crystallized, in six-sided prisms, terminated by pyramidal points, but it also occurs in many derivative forms, its primitive being a rhomboid. It is hard enough to scratch glass, of which, indeed, it is an essential ingredient.

The finest specimens of rock-crystal are found in Dauphiné, in the Alps, in Madagascar, &c., but it abounds in every country, in all parts of the world, in chasms or clefts of the oldest rocks; there are few minerals which do not contain it in a greater or less degree. Quartz often encloses, or is mixed up with foreign substances, which causes it to assume great varieties of colour, and renders such specimens so beautiful in a mineralogical collection. The following precious stones, among others, all consist of simple quartz, deriving their colour and lustre from these foreign admixtures.

Avanturine contains mica in minute lamellar plates; the finest comes from Spain.

Prase is of various shades of green; it consists *of quartz,* enclosing *actynolite,* a mineral consisting *self of quartz, alumine,* lime, and magnesia.

Amethyst is common quartz, coloured by a minute portion of iron and manganese (see IRON and MANGANESE.) The finest come from India, Siberia, and Spain; but it is abundant in most countries.

The Bohemian ruby, Scotch topaz, Bristol diamond, &c., are all varieties of common quartz.

Cat's-Eye is so named from a singular optical effect, caused by the fibrous texture of its substance. It is harder than quartz: it consists of 95 parts of silex, $1\frac{3}{4}$ of alumine, $1\frac{1}{4}$ of lime, and $\frac{1}{4}$ of oxide of iron. It comes from Ceylon and the coast of Malabar.

Opal. The precious stone so called, is one of several varieties of this species. The peculiar play of light, arising from the structure of this stone, is better known than it is susceptible of description. Opal consists of silex and water only, while the other varieties of the species contain various other matters in small quantities.

Flint is the commonest form in which quartz exhibits itself; it is rather harder than quartz, and contains a minute portion of alumine and of oxide of iron; 98 parts in the hundred being pure silex.

A remarkable circumstance attending flint is, that it is found in masses, dispersed in regular parallel beds, in chalk-rocks. This curious fact may be seen in the cliffs near Dover and the Isle of Wight; and it is elucidated and partly explained

in a beautiful manner, by a circumstance that takes place in the manufacture of porcelain. The materials of which porcelain is made are flint and clay, pounded extremely fine, and mingled together with water so perfectly, as to form a smooth fluid, of the consistence and colour of cream; if this fluid be left a long time quite tranquil, the flint separates from the clay, and collects in small masses, in a manner analogous to that in which the natural masses of flint occur in the chalk.

Sand is quartz, or flint, broken fine by the motion of water; flints, rounded by the same force into *pebbles* of all magnitudes, from the size of an ostrich's egg to that of a pea, are found abundantly in all *gravel*, which is a miscellaneous collection of various minerals, ground round and smooth, by being rolled in the bed of the ocean and of torrents.

When quartz is found uncrystallized, and more opaque, of various colours, from white to black, it constitutes *chalcedony*; which differs from quartz in containing more alumine. The following precious stones are only varieties of this mineral, with minute proportions of other matters, as magnesia, iron, &c.

Onyx and *Sardonyx* are stones, composed of concentric layers of differently coloured chalcedony. *When cut, they* present an appearance of irregularly *concentric bands.* Some antique *cameos* were made

from these stones, by leaving the figure or head, in the whiter stratum, while the background was cut down to that which is darker coloured.

Heliotrope and *Chrysoprase;* the former, called also *Blood-stone* and *Oriental Jasper,* from its being speckled with red spots, is a favourite stone with lapidaries to cut into seals, &c. The latter is of an apple-green colour, which is owing to the presence of the metals nickel and iron in small quantities.

Carnelian differs from chalcedony only in being more or less transparent; when first found, these stones are of a dark olive colour, and obtain the lighter red or white hue they are usually seen with, by exposure to the air, and by being baked, it is said, in ovens. The best carnelian comes from the East Indies; but it is also found in Siberia, in many parts of Europe, and in America; it varies in its constituents, from being nearly pure silex, to a mixture of this earth with alumine and iron in small quantities.

Agate, is the generic name of several beautiful variegated stones, generally semi-transparent, and consisting of irregular layers of many of the foregoing siliceous minerals, as *chalcedony, quartz, amethyst, opal,* &c. When cut and polished, the agates present the appearance of waving lines, *sometimes* accurately parallel, sometimes varying

in breadth, sometimes containing a resemblance to vegetable forms, as mosses, ferns, &c. It is considered that these last-mentioned appearances are owing to those vegetables being really enclosed in the stone; this variety is termed *mocha-stone.* Small agates are frequently found in common gravel.

Jasper resembles agate in the number of its varieties and in its structure, but it is opaque. The two genera are nearly allied, and some species are indifferently called agates or jaspers.

Garnet is of eleven various species, all are crystals; the *precious garnet* is found in dodecahedrons, in mica-slate, among the oldest, or *primitive,* rocks in many parts of the world. It is of a beautiful red colour, sometimes with shades of yellow or blue. Those from the kingdom of Pegu are most esteemed, and it is supposed that the *carbuncle* of the ancients was this stone. It is harder than quartz, and consists of nearly equal parts of silex, alumine, and oxide of iron, with traces of manganese. Common garnets are more opaque, of a duller colour, and less hard than the precious garnet, though more so than quartz. They are abundant in similar localities in all countries, sometimes constituting nearly the whole mass of a *rock.*

Most of the foregoing combinations of quartz

are of extreme density, being harder than glass, and capable of striking fire with iron. This property is of great value to us; flint, the most abundant of them, admits of being broken into pieces with a sharp-edge; and when a piece of soft iron is struck smartly against such a flint, small particles of the metal are detached by the blow, while the caloric given out by the collision, heats these particles red hot, forming momentary *sparks*; if these be received on some substance which easily ignites, such as tinder or amadou, a permanent source is obtained for lighting a match. The sparks which a horse strikes up from a paved road, are caused in this manner, the iron shoe coming in contact with a flint. Gun-flints act on this principle, and form an important manufacture, but the most important of all the uses of flint in the arts, is in the formation of glass and porcelain.

Quartz and flint are only fused in the most intense heats, and then require some flux, as an alkali; glass is flint fused with barilla, or soda, or with litharge, (see LEAD.)

We now come to another extensive class of compounds, of which silex is a principal constituent, namely, CLAYS. When these are of a particular structure, called *schistose*, admitting of being split into thin layers of considerable extent, but of *unequal thickness*, they are termed slates, and

constitute enormous strata among the oldest rocks in all parts of the globe.

Clay-slate is of a well-known colour, of various shades; it is opaque, and is easily scratched by iron, but is of different degrees of hardness. It is composed of about fifty per cent. of silex, twenty-five of alumine, and ten or twelve of oxide of iron, the rest being various ingredients in the different varieties. The presence of alumine in this, and all minerals in which it enters in any quantity, may be instantaneously recognised by a well-known peculiar smell which they give out when wetted or rubbed. Clay-slate is used, when split and roughly squared, for covering roofs, also for paving, making cisterns, shelves, and for writing on by means of a piece of the same substance sawed into a small stick like a pencil. Some varieties are used as whetstones.

The common hone used for sharpening edge-tools on, is a variety of slate containing lime and less alumine; it was originally brought from the Levant, but is found in Germany and other places.

Clay is of such infinite varieties in colour, composition, texture, and hardness, as not to admit of any general description. The only species we can notice, are

Porcelain-clay, which, as its name implies, is the *second principal ingredient* in all the better kinds of

pottery. That used in our manufactories at Worcester, comes from Cornwall. In all countries where it is found, it accompanies granite. The superiority of the true Chinese porcelain partly arises from a better kind of this clay being employed, called in that country *Kaolin.** It is composed of silex, fifty-two; alumine, thirty-seven; with some iron. The freer it is from all ingredients but the two first, the better it is adapted for the purpose of making china.

Fullers'-earth. This well-known substance, which is soft, unctuous, opaque, and earthy, is a compound of fifty to fifty-five per cent. of silex, ten of alumine, ten of oxide of iron, twenty to twenty-five of water, with small quantities of lime, magnesia, and other matters. It is found in beds among primitive rocks in many countries, and abundantly in several parts of our own, as in Surrey, Kent, Bedfordshire, Buckinghamshire, &c.

It is used by Fullers to remove the greasiness of woollen cloths, whence it derives its name: servants also employ it for the same purpose, on floors, carpets, &c. Upwards of 6000 tons are consumed annually in this country, 4000 of which are furnished by Surrey alone.

Tripoli, employed in polishing hard bodies, as glass, metals, &c., is a variety of clay, though it *contains* ninety per cent. of silex; it is soft,

rough, of a coarse dull earthy texture; it is found in many countries, but it derived its name from having been first imported from the African town of Tripoli. *Rotten-stone* is a variety of this clay.

Black-chalk, so termed by artists, to whom it is an important article for drawing with, is a *clay* of a bluish black colour, extremely soft, a quality which it owes to the presence of about twelve per cent. of carbon, in addition to its silex and alumine. That most esteemed, is found in Italy and in Germany, and takes its name from those countries respectively.

Pipe-clay derives its appellation from being used in the manufacture of tobacco-pipes. It possesses, in a great degree, a property common to many clays, that of adhering to the tongue. It was used for the old-fashioned Queen's-ware pottery; this clay is found above the chalk on the southern coast of England.

Potters'-clay is of various colours; that used in our potteries for making tiles, jars, stone-bottles, and such coarse ware, comes chiefly from Devonshire: loam, and brick-earth, are varieties of this clay. It is extremely infusible, and contains a greater proportion of alumine than all the foregoing, to which circumstance it owes this property.

There are some other minerals into the composition of which silex enters, but they will be noticed in a subsequent part of this work.

Chapter VI.

OF THE COMBINATIONS OF THE METALS WITH OTHER SUBSTANCES.

Section 1. Of Metallic Ores.

The metals are rarely found *native*, they are usually combined with other substances; the compounds they thus form are called Ores, when the metal exists in them in sufficient quantities to form a considerable proportion of the mass, or to be worth extracting from its value.

Metalliferous ores are usually compounds, either,

1. Of one metal combined with another, or as natural *alloys:* though this state is comparatively rare. One of the ores of silver, which occurs in small quantities in many mines, contains silver and antimony; another, besides these two metals, contains arsenic and iron.

2. Of the metal combined with oxygen, or as an *oxide*. Red chalk is an oxide of iron, found in small masses, in clay-slate.

3. Of the oxide of a metal combined with an acid, or as *metallic salts*. The ornamental stone, *called Malachite*, is a carbonate of copper, or a

combination of oxide of copper with carbonic acid.

4. Of a metal combined with a simple combustible substance, as with sulphur, carbon, &c. Galena, a most abundant ore of lead, is a *sulphuret* of that metal. Pyrites is a sulphuret of iron or copper: Cinnabar is a sulphuret of mercury: Plumbago, or black-lead, is a carburet of iron.

5. Of a combination of two, or sometimes more metals, with one, two, or more earths or alkalies, and even, frequently, with other additional substances. A mineral called Iserine, because originally discovered near the Iser, in Silesia, contains oxides of titanium, iron, and uranium.

Metallic ores do not compose large beds or extensive *strata*, in the crust of our globe; but are usually found in clefts, rents, or fissures, called *veins*, in the strata of rocks.

Section 2. Of Mining.

Mining is the process of getting the ores out of these veins; but this term is also applied to the procuring of other bodies besides metallic ores from the earth: thus coal, salt, diamonds, &c., are *mined* for.

The mode of proceeding in obtaining minerals *from out of the earth by* means of excavations, must

vary as greatly as the position of these minerals, with regard to the mass enclosing them, and the nature of this mass itself. A vein of metallic ore may also traverse strata which are either horizontal, or inclined in different angles, and the strata may be beneath the general surface of the earth, or may compose mountains of every variety of magnitude and form. It would, therefore, be as vain as useless to attempt, in this work, to give more than a mere sketch of the *general principles* of mining.

The mining-operations are the simplest when the vein is in strata, composing elevated hills or rocks or mountains: if the vein be any where exposed at the surface of the ground, the mineral is of course dug out, and the excavation thus made serves as a passage to the interior of the mountain, in following the vein. And when the vein does not appear externally, or when it takes a new direction, after being followed for some distance; access to it is obtained by horizontal galleries, *adits*, or *levels*, dug from the sides of the hill, till the vein is arrived at; similar galleries are sometimes required in order to carry off the water which drains through the higher parts of the mountain, and which would impede the operations, if it were not conveyed away.

When the mineral, as is generally the case with coal, in this country, lies in strata not

elevated above the level of the ground, but considerably beneath it; then, instead of a horizontal gallery, a perpendicular pit, or *shaft*, like a well, is sunk to the requisite depth; and from the bottom or sides of this, horizontal galleries are carried to the beds or veins, or strata sought. It is in these subteraneous mines, that great science and care are required to obviate three difficulties in particular. 1. To afford a support for the superincumbent mass of earth, or rock, which is left without any, by the excavation of the mineral. 2. To *ventilate* the works, or to afford a constant supply of fresh air to the miners, that of these caverns being rendered impure by the breathing of many persons, and by the burning of the lanterns, &c., necessary to light the men at their labours; but chiefly in certain mines, as of coal, by the constant escape from the earth of peculiar gases, which are fatal to life in several ways. And, lastly, to raise out of the excavations the water, which is always found beneath the surface of the earth, and which would collect in the lower parts of the mine, and ultimately fill up the works.

When the mineral mined for is valuable, from not being very abundant, so that it is desirable to take away the whole mass of it, as is the case with many, or most, metallic ores, the *roof*, or part *of the caverns overhead*, formed by so doing, must

INTERIOR OF A CORNISH COPPER-MINE.

be propped up by means of timber beams, or by piers of masonry; the number of which supports must depend on the nature of that rocky roof. In the annexed cut, which represents the interior of a Cornish copper-mine, the *roof* is shown to be supported by timber *shores*, set tolerably close, and the metallic vein, or *lode*, is obviously sloping, or *dipping*, at a considerable angle.

In mines of coal, or salt, or of those minerals which are sufficiently abundant, the whole bed is not dug out, but masses of it are left, like insulated columns, to support the *roof* of the mine; the intervening passages, formed by the excavations, intersecting each other, and forming a labyrinth that would perplex a stranger to thread. On the continent, where less capital can be devoted to such works, and where less attention is shown to the safety of the labouring classes, accidents have frequently occurred from the falling in of the roofs of mines, sufficient attention not being paid to the supporting of the rock above.

The proper ventilation of a mine is a point of the highest importance: the mode adopted is to cause a current of fresh air, from the surface of the earth, to descend one *shaft*, or one half of a shaft, to supply the place of the impure, or noxious air, which is caused to rise through another shaft, *or through the* other half of the same. This ascent

of the bad air is effected, in most cases, by large fires made at the bottom of the shaft; the air in which, being thus heated, ascends, as all hot air does, and causes the upward current, this being supplied by the air of the mine; and to obviate the formation of a vacuum, fresh air must descend into the mine by another passage.

In extensive mines, shafts are frequently sunk for the express purpose of allowing the access of fresh air from the surface; but in smaller works, or in those where another shaft cannot be afforded, the main shaft is divided into two by a vertical partition of planks; and the fires being kindled immediately under one of the passages thus formed, the other is left free for the descent of the cold air. Dreadful accidents having, however, occurred from the wooden partition catching fire, and thus cutting off all escape to the unfortunate miners who were in the galleries and chambers, this mode of proceeding is gradually falling into disuse, at least in this country.

Where, from the nature of the rock or soil, and of the mineral contents of a mine, ventilation is only required to remove the air injured by the breathing of the workmen, and by the burning of the lights, it is easily effected. But in mines of *certain minerals*, and in those that are excavated *in particular soils*, gases exude from the earth,

which are fatal or injurious to breathing, and which, when mingled with the air of the mine, render it unfit for respiration. In coal-mines such a gas is produced in large quantities, which, in addition to its being unfit to be breathed, possesses the dangerous quality of exploding when mixed with common air, if accidentally set fire to, and is thus destructive of life by a double action.

This gas, generated in coal-mines, which is a species of *carburetted hydrogen*, or of the gas employed for the purpose of illumination, being specifically lighter than atmospheric air, ascends to the roof of the mine. If this be lofty, the gas floats over the head of the miner without causing any serious effects, till its volume, enlarged by continued additions, causes it to occupy so much space as to bring it within the height of a person's head, standing on the floor; but long before this, the second cause of danger is in operation; the lanterns or candles of the miners being continually liable to ignite the mass of gas, and to cause an explosion.

To obviate this second source of danger, the late Sir Humphrey Davy invented the *Safety Lamp*, which admits of a light, enclosed in this instrument, being employed in the midst of the inflammable gas, without setting it on fire; while the increasing *dimness of the lamp*, caused by the unfitness of the

air for supporting combustion, warns the miner of the dangerous increase of the fatal gas, and enables him to retire in time.

It is in coal-mines, therefore, that the greatest care, and the most systematic method of ventilation is required; and in extensive mines many additional shafts are sunk, at great expense*, solely for this purpose. Yet, with all the precautions, suggested by experience, aided by science, and supported by humanity, not a year passes without many dreadful accidents occurring in our collieries.

The liability to these accidents is greatly increased by the practice of *blasting*, or of employing gunpowder to detach masses of the mineral: a proceeding by which manual labour is economised.

It has been already mentioned that, in mines situated in elevated hills, *day-levels* serve to convey off the water; and when this arrives at the side of the hill, the natural fall of the ground offers the readiest and most effective mode of drainage. In one district of the Cornish mines, there is a series of adits, branching off from different works, forming a continued line of excavation of nearly thirty miles

* The cost of sinking a shaft in a mine may vary from 10,000*l.* to 150,000*l.*, but, of course, those created solely for the purpose of ventilation, are not so expensive as when they are to be adapted *to serve as passages* for ingress and egress; and for raising the *coal, or ore.*

in length, and finally discharging the accumulated waters into Falmouth harbour.

But when the mine is below the level of the sea, the water, which, in such situations, accumulates in the greatest quantity, can only be got rid of by raising it to the surface of the earth by means of pumps, worked by water-mills, or by steam-engines.

The first shaft, which is called the engine-shaft, is always sunk lower than any other belonging to the same mine; and the water is brought by horizontal adits, from the other pits and galleries, into this shaft, at the bottom of which it collects; and at different stages of the shaft, powerful forcing-pumps are erected, the pistons of which are worked from above, by chain-work from the main engine. In some mines, upwards of 800 gallons of water must be pumped up every minute, to prevent the works from being inundated; so great and so rapid is the accumulation. The largest and most powerful steam-engines ever made, are thus employed at some of our mines.

In pursuance of the plan of this work, we shall now proceed to describe the *metals*, in the order in which they were enumerated at p. 7, and to give a concise account of their natural history, uses, and the modes by which they are obtained.

Chapter VII.

Section 1. Platinum.

This metal is of a bluish-white colour; its specific gravity is 21·5, it being the densest and heaviest of all bodies. It is not easily affected by exposure to air or heat; it therefore ranks as one of the *pure* or *noble* metals, as they used to be called. It is soft, malleable, ductile; only inferior in these qualities to gold and silver; in tenacity it only yields to iron and copper.

The proportion of the principal metals in this respect is as follows: Iron 270, Copper 157, Platinum 124, Silver 85, Gold 68, Tin 24, Zinc 12; these numbers expressing the proportionate weights which wires of these different metals, of equal diameter, will support without breaking. A platinum-wire, one-tenth of an inch in diameter, will sustain a weight of 361 lbs.

Platinum is, comparatively, a slow conductor of heat, and is one of the most infusible of metals; it is capable of being welded (see Iron); and to this valuable property we are indebted for its practical utility, since no article can be made from it by *casting*. Like Gold, it is only soluble in Nitro-*muriatic acid, and in* chlorine.

Platinum was discovered by a Mr. Wood, in Jamaica, in 1741; it was first obtained from Choco and Santa Fé, in South America; it is also found in St. Domingo, Brazil, Spain, and most abundantly in the Ural Mountains, in Siberia. In 1830, 9500 lbs. weight was obtained from these mines. A piece of native platinum, weighing 20 lb. was found in one belonging to Count Demidoff. Its name, which means *little silver*, is derived from *Plata*, the Spanish term for silver. Platinum is found native, or only alloyed with Iron, Copper, Lead, Gold, Silver, Palladium, Rhodium, Iridium, and Osmium, and in nearly the same circumstances and localities as gold, in the sands of rivers; but, as yet, not in veins in rocks.

The grains of the metal, after being freed, by chemical processes, from the other metals with which it is alloyed, are pressed forcibly into a mould, till they adhere in an imperfectly-solid form; the mass is then heated to a white heat in a blast-furnace, and hammered till it is rendered uniformly dense and solid. The process varies in different countries, though the principle is the same in all.

By greater skill and improvements in these methods, platinum is now sold in the metallic form of ingots, at about fifteen shillings an ounce. A quarter of a century ago, it was at three or four *times that price.*

The late Dr. Wollaston succeeded in drawing out a wire of this metal to the fineness of $\frac{1}{10}$,$\frac{1}{000}$, or $\frac{1}{18}$,$\frac{1}{000}$ of an inch; and it then supported $1\frac{1}{3}$ grain in weight without breaking. He accomplished this by putting a wire of platinum of $\frac{1}{10}$ of an inch, drawn in the usual way through iron draw-plates, in a cylindrical mould, and filled this up with melting silver. This silver cylinder, enclosing the platinum-wire, was then drawn out to $\frac{1}{30}$ of an inch in diameter, and the silver being removed, by dissolving it in nitrous acid, the platinum-wire was left free, of the extreme fineness above-mentioned.

A fulminating powder can be prepared from the sulphate of platinum, similar in its action and effects, to that prepared from Gold, Silver, Mercury, &c., (see the accounts of these Metals.)

Platinum is principally used in forming vessels for chemical operations, as crucibles, &c., for which it is admirably adapted from its infusibility, and from its being so slow a conductor of heat, that a short slip of the metal may be heated by a blow-pipe to a white heat at one end, and held in the naked hand at the other.

A platinum retort, capable of holding 300 pounds of sulphuric acid, has been used for concentrating it by distillation, in a manufactory of that article.

An oxide of platinum is used in porcelain

painting for silvering, in that species of ware called *silver-lustre.*

In Russia platinum is coined into money, and circulates to some amount.

It is also employed, instead of gold, in making the touch-holes of fowling-pieces, &c., as not *burning* or oxidizing by use; and a more innocent and useful application of it, as an alloy of copper, is to the forming of mirrors, or *specula*, for reflecting telescopes, which are less liable to tarnish than if made of other metals. The difficulty of working platinum has made the articles, in the fabrication of which it is employed, so expensive, as to limit, in a great degree, the uses which might otherwise be made of this valuable metal.

Section 2. Gold.

This metal, when pure, is of a rich yellow colour, but varying in its shades: its specific gravity is 192, or nearly as great as that of platinum. It does not easily combine with oxygen, hence it does not rust if exposed to the air, so that it can be melted over and over again, without any great diminution of its quantity, by the formation of an oxide*.

* Gold has been kept in a state of fusion in the furnace of a glass-house for nearly eight months, without undergoing any *perceptible change.*

It is inelastic, soft, more malleable and ductile than all other metals; it can be hammered, as will be presently explained, into leaves only the 282,000th part of an inch in thickness, without losing its adhesion, or so that one grain, in weight, will cover 56¾ square inches. In this state of thinness it is found to admit of the green rays of light passing through it.

In tenacity, however, it is inferior to iron, copper, platinum, and silver. A gold-wire one-tenth of an inch in diameter, will only support a weight of 191 lbs.

It is fusible at a temperature of about 2000 degrees of Fahrenheit's scale; no heat that can be obtained in any furnace volatilizes it, but this has been done by solar heat, through a lens; by an electrical battery; and also by a gas blow-pipe. It is the most rapid conductor of heat of all substances.

Gold is only soluble in nitro-muriatic acid, and in a solution of chlorine.

Gold has been known from the earliest ages.

It is by no means a rare metal, though not so universally diffused as iron, lead, silver, or copper; its superior value depends, like that of all other *substances*, on the quantity of labour requisite to *obtain it*.

Gold is only found in the metallic state, or native, but always more or less alloyed by other metals. It occurs crystallized in the primary form of the cube, the regular octohedron, and their derivatives, in veins in mountains in many parts of the world, the veins being usually filled up with *quartz*, or rock-crystal; it is also found in company with the ores of silver, with sulphurets of lead, copper, &c.

But the greatest quantities of gold are met with in the sands of rivers, and on the surface of the earth, in small grains, or pieces of irregular forms and sizes, in most countries.

In the time of Queen Elizabeth, it was found in considerable quantities in the alluvial soil near the lead-hills of Scotland, and in Cornwall in several of the *stream-works* of that county; one specimen weighed as much as ten guineas: it is also found in the refuse of the Prince Regent mine in Devonshire, in grains and plates, imbedded in a quartz rock. A few years ago as much as one thousand ounces were found in the alluvial soil at Croghan Kinshela, county Wicklow, in Ireland. One piece weighed twenty-two ounces; in this instance it was alloyed by silver. Lumps of gold have, however, been found in some countries, weighing as much as thirty to forty pounds, but such specimens are *extremely* rare.

The richest mines of Europe are those of Hungary and Transylvania, there being no less than forty worked in these provinces, producing annually about 50,000 ounces of gold. The mines of Schemnitz, in Lower Hungary, have been worked ever since the twelfth century; they lie in a small basin, in the midst of barren mountains. All the mines terminate at a common *level*, or gallery, about six hundred feet below the surface; from this the water is conveyed by means of a subterranean gallery, twelve miles long. The shafts and galleries are well cut, and kept in good order; the rock decomposing rapidly renders it necessary that they should be cased with wood, and as this requires frequent renewal, the expenses of the establishment are very great.

The veins of the Hungarian mines are the largest in Europe, being rarely less than from eighteen to twenty-five feet, and in places upwards of one hundred and twenty feet thick; they are not, however, very extensive, and fall far short of the celebrated vein of *Ventamadre*, in Guanaxuato, which, with a breadth of from one hundred and twenty to one hundred and forty feet, has been worked to a distance of nearly three leagues.

Sulphate of silver, and *galena*, or *sulphuret of lead*, are the most abundant ores at Schemnitz; the former, where richest, and freest from foreign matter,

yields about 80 lbs of silver in the hundred weight. The gold is, in general, proportionately abundant to the silver, at the rate of one to thirty, and is procured from the same ore. For an account of the method of obtaining the gold from the ore, see the metal MERCURY.

The produce of these mines is declining, from the injudicious methods pursued: the process of *amalgamation* having been abandoned, from prejudice to the person who introduced it.

Gold has been obtained for upwards of thirty years, in continually increasing quantities, from mines in the Russian provinces in Asia.

In Africa, where, from the limited population and want of cultivation of the people, labour is worth little, considerable quantities of gold are obtained by the Negroes, by washing the sands of the rivers.

Mungo Park gives the following account of the usual modes of proceeding for this purpose. "About the beginning of December, when the streams and torrents, which are supposed to wash the gold down from the mountains, have subsided, parties of men and women, under the orders of a chief, proceed to the proper spots; each person having a hoe, or spade for digging, two or three *calabashes*, (the hollow fruit of a plant resembling a gourd, *much* used in tropical countries for holding

liquids,) and a few quills for containing the gold when procured.

Some begin washing the finer sand, while others search those places where only the larger pebbles have been left by the force of the current, for among these the larger pieces of metal are also deposited from their greater weight, while the smaller grains are carried on further with the finer sand.

In the dry season, a pit is dug near a hill, known to contain gold, the sand or clay is put into calabashes to be washed; one or two calabashes full are washed on the spot for experiment, in order to ascertain whether the earth contains any metal; if it do not, they dig until they come to a stratum that does. When the soil is a fine reddish sand, containing small black specks, it generally contains more or less gold.

The proper earth being obtained in the vessels, these are given to the women to search, and they do this by washing the earth and clay in repeated changes of water; shaking the calabash dexterously, so as to throw out the dirty water and the clay, and to leave the sand which contains the metal. When the water comes off clean, the sand is poured out into another calabash, leaving the lower portion of sand which usually contains the *greatest number, or the* heaviest pieces of gold;

this portion is mixed up with fresh water, and carefully examined, and the grains of gold picked out; if two or three are found, the other vessel is then proceeded with in the same way, and if half-a-dozen grains are procured from both, the search is considered profitable.

The gold thus collected is put into the quills, and stopt up with a piece of cotton; the women wear these quills containing gold, by way of ornament, in their hair; and they are afterwards bartered away to itinerant merchants, for salt and other commodities. A portion is retained by the wealthier for ornaments, and some Negresses, when full dressed, have from fifty to eighty pounds' worth of gold on their persons, made into massy earrings and armlets.

A skilful and active person will, in a favourable dry season of eight months, collect as much as forty pounds' sterling worth of gold in this way; but, from want of knowledge, they do not search in the most favourable situations, and frequently the labour is very unprofitable and unproductive.

At Sofala, on the south-eastern side of the Peninsula, gold is found, not only in *alluvium*, but also in veins. It is conjectured that the Ophir of Scripture was situated on this coast.

America furnishes the far greater portion of the gold employed throughout the world.

In Brazil, gold is found in alluvial sands, as in Africa; the mining district is called Minas Geraes; the soil is red, having iron in it, and in many places of great depth. The gold lies principally in a bed of rounded pebbles, called *cascalho*, immediately over the solid rock. Where water can be obtained, so as to flow over the spot, the ground is cut into a succession of terraces, or steps, about twenty or thirty feet long, two or three broad, and one deep; at the bottom a trench is cut, two or three feet deep. The water, flowing over these steps, is stirred about by five or six men, who stand on each, so that it washes down in thin mud, carrying the gold with it; this, by its greater weight, falls to the bottom of the trench. Workmen are stationed along this, who keep clearing out the earth and stones, and they are much assisted in this operation, by the stream of water which is constantly flowing in.

After five days washing in this way, what remains in the trench is carried away to another place in the stream, to undergo further purification and search. This is effected by taking a portion of it up in shallow wooden bowls, with a little clear water; the whole is then shaken round and round, so as to allow the gold to subside to the bottom and sides. The contents of the bowl are then poured into another vessel of clean water, and a fresh bowlful

taken, each quantity occupying from five to eight minutes. An overseer watches the process to prevent embezzlement.

The gold obtained in this way is in grains, from the smallest visible size to about that of a pea, and occasionally much larger. It is placed on a brass pan, over a slow fire, to be dried; then taken to an office where a fifth is deducted for the royal dues. The remainder is mixed with mercury, which *amalgamates* with the gold, and separates it from the impurities which are mixed up with it; the mercury being afterwards driven off by heat, the gold is left tolerably pure, and is then cast into ingots, *assayed*, or examined chemically as to its purity, and stamped accordingly. These ingots pass for money in the country.

These processes vary in different districts, according to the abundance of water and fall of the ground, but in all, the general principle is the same; and is also practised in New Grenada and Chili.

There are some circumstances respecting the *precious* metals, gold and silver, that render it extremely difficult to arrive at even a tolerable estimate of the quantity obtained from the earth, and of the distribution of that quantity.

These metals are comparatively imperishable, while their value and utility cause the utmost care

to be taken of them; hence the quantity annually obtained, forms but a small addition to the vast accumulation of preceding centuries.

Most governments, from erroneous notions as to what constitutes wealth, have laid a claim to a large portion, if not all, of the precious metals excavated from the earth, hence the *farmers*, or the *proprietors*, of the mines producing them, have a direct interest in concealing or mistating the annual produce; while, in common with all other things, that actual produce is very uncertain and fluctuating.

The employment of gold and silver for money in most countries, while it affords a tolerably constant measure of the value of other commodities; causes considerable embarrassment in estimating the value of these metals themselves: and their different value, in different countries, together with the different denominations of the coins formed of them, increase these difficulties in an almost insurmountable degree.

The adoption of paper, as a substitute for metallic currency, again causes the quantity of gold and silver, devoted to this purpose, to be perpetu-
, that portion which is abstracted being
nted to the arts, or to the luxuries of

ntries, and in all ages, the facility of
a large property in the shape of

for the purpose of securing it from plunder, during times of foreign invasion or domestic convulsion, has been productive of enormous loss, in the quantity of the precious metals accumulated; for these deposits are frequently forgotten, the owner either dying without mentioning their existence, or himself forgetting, if he survive, the precise spot to which he confided his treasure.

Large sums are often lost, too, by shipwrecks, when bullion or coin is conveyed from one country to another for the purposes of trade; and the quantity, which is annually employed in gilding and plating, and, therefore, eventually destroyed, is almost unappreciable, though probably not very considerable.

From these causes, hardly two writers agree in their statements on this subject; instead, therefore, of attempting to give any account of the absolute quantities of gold or silver, obtained from the various countries, furnishing us with the principal supplies, which statements must be vague; we shall only mention a few facts on this subject, taken from the best authorities, which will enable the reader to draw his own conclusions.

It is estimated that the entire annual produce, in gold and silver, of all the American, European, and Russia-Asiatic mines collectively, amounts to *6,000,000l.* sterling, on an average of the last

twenty or thirty years, this sum being only six-tenths of what it was, when the principal mines, those of America especially, were most productive.

From the year 1790 to 1809 inclusive, the four principal mining districts, Mexico, Panama, Chili, and Buenos Ayres, furnished 7,473,825*l.* of gold, and 114,660,870*l.* of silver, a total of 122,134,695*l.* or about 6,106,735*l.* annually on an average.

From the year 1810 to 1829 inclusive, the same sources yielded 6,003,132*l.* of gold, and 54,162,760*l.* of silver, a total of 60,165,892*l.*, or about 3,008,294*l.* annually on an average.

During the last period, the Russian mines have furnished 3,703,743*l.* of gold, and 1,502,981*l.* of silver.

The gold annually obtained in Africa is not taken into consideration, partly because it is comparatively but small in quantity, and that quantity is not at all accurately known; and partly because, whatever the amount may be, but little of it ever comes out of that continent, to augment the supply of civilized nations.

The *quantity* of gold was to the quantity of silver produced in America, at the commencement of this century, as 1 to 46; and of that produced in Europe 1 to 40. The *value* of equal quantities was *15 or 15½ to 1.*

Of the annual supply of precious metals it is

estimated that from 3,650,000*l.* to 3,760,000*l.* are employed in the arts: and about 2,000,000*l.* for coin.

One per cent of that used in coin is annually lost by wear, tear, fire, shipwrecks, &c.

Britain is supposed to consume of the annual supply 1,842,916*l.*, France 866,200*l.*, Switzerland 350,000*l.*, the rest of Europe 1,205,000*l.*, and 300,000*l.* is allotted to America.

It has been a constant source of lamentation among those mistaken persons, who in all times have fancied that gold and silver alone constituted wealth, that an enormous quantity was annually sent from Europe to the East, in return for the varied supply of commodities, furnished us from that fertile region. These alarmists may now be consoled, for there is authentic testimony to show that the current has turned, and that now more bullion comes to Europe from Asia than goes to it.

The principal uses of gold, in civilized countries, are either for vessels and ornaments, or for money. For the latter purpose it is particularly well adapted by its qualities; its power of resisting the action of the atmosphere, and of not oxidizing, or rusting, as most other metals do, causes coins, made of it, to last and retain their colour, and the sharpness of the impression stamped on them, for a great many years; the facility with which gold can be remelted

with little loss, admits of its being coined over and over again; its softness and density allow of its receiving a sharp and clear impression from a steel *die* or stamp; while its value causes a small and portable piece to be equivalent to a quantity of goods, or other metals, in the form of coins; thus one gold sovereign, in England, is equivalent to twenty silver shillings, each a little larger than itself, and to 480 copper halfpence, nearly twice its size.

Gold is never used quite pure for the purpose of coining, because, in that state, it would be too soft to bear the constant rubbing it is subjected to in circulating as money. In England, gold for coin is alloyed with two parts of copper to twenty-two of pure gold.

The beauty of its colour, its brilliance, as well as its value, cause gold to be much employed as a luxury, in ornaments for the person, in vessels and plate for the table, and in furniture; for the former purposes it is more alloyed than for money; *jewellers' gold*, as it is called, being a mixture of eighteen parts of pure gold and six of copper.

But though it is only the rich who can afford to have large articles made of solid gold, the contrivance of *gilding*, as it is called, places all the *external* beauty of the metal within the reach of *the less prosperous.*

Gilding is the art of covering articles, made of inferior metals, with a thin coating of gold; this is applied, in *leaves*, on the surface to be gilt, which is first thoroughly cleaned and polished, and then heated: the gold leaf is burnished on with a blood-stone, till it adheres to the metal; and this operation is repeated till the coating is sufficiently thick and even to be durable.

But a better mode of gilding is now chiefly employed, by applying an amalgam of gold (see MERCURY) on the smoothed and cleaned surface of the article to be covered; this is subsequently exposed to such a heat as to cause the mercury to fly off in vapour, leaving the gold spread evenly over the surface.

When the metal to be gilt has not sufficient *affinity* for mercury, to allow of the amalgam adhering to the surface, the article is first prepared by cleaning and burnishing as before; it is then dipped into a solution of mercury in nitric acid, by which means it becomes covered over with a thin coating of that metal, and thus causes the amalgam to adhere firmly when applied in the usual way.

The gilt goods are heated in ovens, built in a peculiar form, so as to collect again the greatest part of the mercury of the amalgam; this being too valuable to be lost. So economical is this

simple and beautiful process, that one hundred and forty-four buttons, of an inch in diameter, can be gilt on both sides by only five grains of gold.

It may be easily supposed that many variations in the process are necessary, according to the kind of article to be gilt; but the general principle is the same for all.

Polished steel may be gilt by dipping it into a solution of chloride of gold in sulphuric æther, and then plunging it immediately in cold water.

Those substances, such as wood, leather, &c., which will not allow of the application of heat, are gilt by means of leaf-gold being fixed on them. This leaf-gold is prepared in the following way: A small thin bar of pure gold, weighing about two ounces, is drawn repeatedly between hard polished steel rollers, in what is termed a *flatting-mill;* the rollers being brought closer and closer each time, till the metal is expanded into a long strip, like a ribband, and equally thin in every part; this is cut by shears into small squares of an inch, and the waste pieces carefully collected to be re-melted; a square of the metal is then put alternately with a piece of fine calf-skin, till a parcel of a hundred and fifty is made up, with about twenty thicknesses of skin placed at the top and bottom; these leaves *of vellum* are about four inches square, or two *inches each side.* The packet is next put into a

parchment case, and another again drawn over that, so as to confine the whole securely: it is then beaten by hand, the workman using a heavy hammer, of about fifteen or sixteen pounds weight, in one hand, and turning the packet about with the other, on a heavy piece of marble, about a foot square, let deep enough into a solid block of wood; so that this shall form a ledge round three sides, while a leather apron is fixed on that next the man for the purpose of catching any portion of gold that may escape in the subsequent operations.

The packet is beaten in this way till the plates of metal are extended by the operation to nearly the size of the vellum squares, the leaves of the metal are then cut into four, by drawing a knife across them in two directions, so as to reduce them to about their former size. These squares are then made up into packets of the same number as before, but finer skins, prepared from the intestines of the ox, and termed *gold-beaters skin*, are placed between each leaf, instead of the vellum; the beating is repeated, but with a lighter hammer, of about ten pounds weight, till the metal is once more expanded to the size of the leaves.

The leaves of gold being laid on a cushion, are then again divided by means of two pieces of cane, cut to sharp edges, and fixed on a light frame, at right angles: the squares are for a third time

made up into packets, and re-hammered till they are extended to the size of about three and a half inches square, and the metal of such a thinness as would cover a surface 192 times as large as it would before the beating; as the plates at first were an inch square, and seventy-five of them only weighed one ounce, this ounce is extended by the hammering, so as to cover 14,400 square inches, or 100 square feet.

These leaves are next cut square and smooth at their edges, by the canes, and are placed in books of soft paper, made of pieces folded once, but not sewed; each page is rubbed over with red ochre, to prevent the gold leaf from sticking to it.

In this form it is sold to painters and gilders, and it is applied to the surface to be gilt, in the following manner: the surface being first brushed over with size, the book is opened, and the enclosed gold leaf pressed on the surface, till the whole is covered; when the size is quite dry, the superfluous part of the metal is rubbed off with a piece of cotton. In this way every one must have observed painters gilding the letters over shop-doors, &c.

But this is far from being the limit to the ductility of gold; the gold thread employed in embroidery, is obtained by casting a cylinder of silver of about 360 ounces in weight; which is then covered

with a coating of gold leaves, weighing altogether about 6 ounces, thus making in all about 366 ounces. This cylinder is drawn through holes in iron plates, gradually diminishing in diameter, till it is extended into a fine wire, as thin as a hair, and above 200 miles in length! to effect this it is passed through more than 140 holes. And yet this fine wire is, for its whole length, composed of a silver wire, equally and every where covered with a coating of gold, which cannot exceed $\frac{1}{490,444}$ part of an inch in thickness, and in some cases is even as thin as $\frac{1}{2,100,000}$ part of an inch. If this wire be dipped in nitrous acid, which dissolves silver but not gold, the silver central-core is removed, leaving the thin coating of gold like a hollow cylinder *.

If a solution of gold be made in nitro-muriatic acid, and a bar of pure tin be dipped into the liquid, the powder which is precipitated is known in commerce by the name of the purple precipitate of Cassius, from its inventor, and is generally used for forming purple and violet colours in enamel and porcelain painting.

Gilding on porcelain and glass, is performed by grinding leaf-gold with honey, or gum water, this is washed away, and the metallic powder, when dry, is preserved in shells or papers, and is hence

* This is perhaps the nearest approach to the ultimate subdivision of matter attainable by mechanical means.

known by the name of *shell-gold.* This powder is mixed with gum-water, or oil of lavender, as a medium, and is applied on the porcelain like any other colour; it is burnt in, in an oven in the usual way, and afterwards burnished.

This kind of gilding on china can also be applied in the same manner as on other substances; by laying leaf-gold on the pattern painted in gum-water, in which a fluxing material is mixed: when the gum is dry, and the superfluous gold removed, the ware is burnt in the oven, and the flux causes the metal to combine with the substance.

A preparation of gold is obtained from a solution in nitro-muriatic acid, which is called *fulminating gold**, from its exploding with great violence on being slightly heated, or on being struck, or even by being rubbed. In these qualities it is only inferior to fulminating silver, (see SILVER.) This compound is used in porcelain painting, for giving a carmine tint.

As a medicine, gold is not at all, as yet, employed in England, though in Germany, in the new system of practice, which is extensively spreading, this, as well as many other metals, which are not considered as medicinal here, are used for that purpose.

* *This, and other analogous* preparations, are so dangerous in *hands of unskilful persons,* that no directions for preparing *will be given in this work.*

Section 3. Tungsten.

Tungsten is a greyish-white metal, with a specific gravity of 174. It is as infusible as platinum, and has only been obtained in a granular form; the grains are so hard as scarcely to yield to a steel file.

One of its oxides constitutes an acid, which is found combined with lime, &c., in nature.

The metal has been artificially combined in alloys, with gold, silver, copper, iron, lead, tin, antimony, bismuth, and manganese; but from the extreme infusibility of the tungsten, these alloys are formed with difficulty, and have not been applied to any purpose in the arts.

Tungsten was discovered by some Swedish chemists of celebrity in 1781. It is found in three ores; an as oxide, in the mineral called Wolfram, which is a tungstate of iron, met with in the tin-mines of Saxony and Bohemia, and in Cornwall; and in tungstate of lime, called Tungsten, a Swedish word for heavy stone, in which the metal was originally discovered, found in the same localities as the last.

Section 4. Mercury.

This metal is of the same colour as burnished silver, its specific gravity is 135, or 13½ times that of water, its density is, consequently, next to those of platinum and gold.

The most remarkable circumstance connected with mercury is, that it fuses at a temperature of 39 degrees below the zero of Fahrenheit's scale; or 71 degrees below the freezing point of water: consequently in the metallic state it is always fluid or *melting*, unlike all other metals with which we are acquainted. Hence its uses are totally different from those of other metals; yet there are but few more important to man in many ways. From its fluidity and colour, it is commonly called *quick-silver*.

In the intense cold of the polar regions, mercury occasionally freezes, or solidifies; and when in this state, it is probably malleable and ductile, like other metals: but in such circumstances it is impossible to touch it, the contact causing a pain like that of hot iron, and the texture of the flesh being speedily destroyed, and mortifying. It has also been congealed artificially in laboratories, during severe winters, when the thermometer was at zero.

it then crystallized in octohedrons, and bore being hammered a little.

Mercury boils at a temperature of 680 degrees, and is converted into vapour of a highly expansive force: this vapour can be condensed again into the fluid metal, as steam is into water, by being received in cold vessels.

Mercury has less affinity for oxygen than most other metals, it may be distilled over 500 times without loss of quantity. It does, however, combine with oxygen in two proportions, forming a black and a red oxide: by simple heating in a retort the gas is driven off, and the metal obtained pure again.

One of its combinations with chlorine is the celebrated medicine *Calomel:* and another is the highly poisonous substance, called *corrosive sublimate.*

Cinnabar and *Vermilion* are compounds of mercury with sulphur, or are *sulphurets of mercury.*

Mercury unites readily with many, and has a strong tendency to unite with all metals; the compounds it forms with them are called *amalgams* (from a Greek work meaning to soften,) because these alloys are soft instead of hard, like those of other metals.

The readiness with which it unites with gold or *silver, and the* facility with which it is again sepa-

rated from them, by heat, renders mercu
importance in obtaining those metals fro
and alloys, in mining operations.

The ore, having been sorted, clea
pounded, to free it as much as poss
earthy matter, is put into wooden boxes, fo
with plates of cast iron: and is then a
pounded by heavy beams of oak, shod with ir
worked by a water-mill or steam-engine, by this
means the ore is reduced to a fine powder. It is
then wetted in another vessel, with salt and water,
and the workman, taking a bag, made of thin
leather, filled with mercury, forces this metal,
in a shower of minute drops, through the leather
by pressing it over the ore: the whole is then
stirred up, fresh mercury is added, and intimately
mixed with the mass, till a quantity, sufficient to
amalgamate the gold, has been incorporated with
it: to facilitate this the mass is rubbed and pounded
with wooden pestles, and kept heated to the tem-
perature of boiling water, for three or four days.
The mixture is then washed carefully in small por-
tions, till all the earthy matter is separated from it,
and the amalgam alone left. Part of the mercury
is next separated by simple pressure in leathern
bags, and the remainder distilled off by heat,
aving the gold or silver only alloyed with the
etals with which they are chemically united in

the ore; from these metals the gold or silver can only be freed by chemical processes.

This mode is generally employed in the gold and silver mines, both of Europe and America.

The use of amalgams in the process of gilding or plating is mentioned elsewhere, (see GOLD and SILVER.)

An amalgam of four parts of mercury with one of bismuth, is made use of to excite the action of electrical machines.

But a more extensive use is made of an amalgam of tin, in *silvering* mirrors; this interesting process is conducted in the following manner.

A perfectly flat and smooth slab of stone or wood, rather larger than any plate of glass which is to be silvered, is enclosed in a wooden frame, leaving a ledge, a few inches deep, round three sides; there is a gutter, round the frame, to collect the superfluous mercury that escapes, and a vessel to receive it is placed beneath; the slab has a contrivance by which one end may be raised at pleasure.

This table being set truly horizontal, is covered over with blue paper, stretched lightly on it; and on this a sheet of tin-foil is laid, a little larger each way than the glass: on this foil, mercury sufficient to cover it is poured gently, so as to lie every where of an equal depth, the end of the slab that was left without a ledge being covered with strips

of parchment, over which the glass is slid, the greatest care being taken that the front edge shall dip into the fluid metal, and so push a portion of it before it. By this precaution, all dust or tarnish which may have settled on the surface of the metal is carried off, and no air bubbles can get between the glass and the mercury: on the other hand, if the edge of the plate dipped too deep into the metal, so as to touch the foil, this would be torn, and the whole process rendered vain.

When the glass is passed quite on to the foil, it is allowed to drop down gently on it, squeezing out, by its weight, all the superfluous mercury, which is received into the gutters, and saved; thick flannels are then spread on the top of the glass, and heavy weights are placed at regular intervals, to compress the glass and foil together. The end of the slab is raised a little, to favour the escape of the mercury, which is thus squeezed out: it remains in this state for a day or so, and is then carefully taken from the table, and placed in a wooden frame, where it is kept till the amalgam is thoroughly hardened.

Mercury has been known from the remotest antiquity, and its powers of separating the precious metals from their ores, by amalgamation, have been made use of from the earliest ages.

Mercury is found native in globules, mixed up with its other ores. A natural amalgam of mercury and silver is found in some localities, either in a semi-fluid state, or crystallized in various forms: and it is so easily separated from many minerals, that the warmth of the hand is sufficient to make it exude from some of these.

It is far from a generally diffused metal, though its ores are numerous; that from which the metal is principally obtained is the sulphuret, which is thus treated.

The ore, being brought out of the mine, is sorted with considerable care, to separate all those pieces that contain little or no metal; it is then reduced to powder, and mingled with about one-fifth of its bulk of quick-lime, reduced to powder by exposure to the air. This mixture is put into large iron retorts, forty or fifty of which are placed in a long furnace; glass receivers are put to the ends of these retorts, and seven or eight hours of a full red heat is sufficient to distil over the metal; six or ten ounces of which is obtained, on an average, from 100 lbs. of ore.

The metal is packed in sheep-skin bags, with the hair taken off, these are enclosed in a second and third bag, of the same materials, and four are pressed into very tight barrels for exportation.

These precautions are requisite on account of the subtle nature of the fluid metal.

The principal mines of mercury are in Peru, in America; in China, and in Spain, Bavaria, &c.; but the most celebrated are those at Idria, in Carniola, which have been worked from the beginning of the sixteenth century. It is said that a peasant, taking water from a spring, to try a new tub, was astonished at finding some metallic globules left at the bottom of the vessel; surveys took place, which gave rise to the opening of the mines in 1525.

The metallic vein is situated about 240 yards deep, it extends 2400 feet in one, and 3000 feet in another direction; and lies in a valley, elevated 500 feet above the level of the sea: there are six *shafts* to the mine, three of which are for drawing up the mineral, and one for pumping out the water. The mine is entered from within a spacious building, in the middle of the town of Idria, by a passage, leading almost horizontally, under a lofty vault, to a staircase of stone and wooden steps, constantly kept in excellent repair, reaching to a depth of 450 feet; the remainder of the descent is accomplished by wooden ladders, from one landing place to another, having benches for persons to rest on: the whole mine is kept remarkably clean, and in good order. *The subterr*aneous excavations consist of nine

horizontal principal galleries, with many others branching from them, about seven feet high and wide, and arched over to keep the rock from falling in.

The temperature in the mine, in some parts, is from 80 to 95 degrees. The mineral products are so varied, and so confused together, that the mine is unlike any other in the mode in which the operations are carried on; in some places pure mercury distils in globules from the rock, and a miner is said to have collected 36 lbs. of it, in this manner, in six hours.

The ore is raised up in square boxes, by means of a water-wheel, turned by an artificial canal from the Idrixa.

Besides metallic mercury obtained from the ore by distillation, all the important preparations of mercury, used in the arts and in medicine, are either found naturally, or are manufactured at Idria, in spacious laboratories erected for the purpose.

The produce of the mine, though varying, may be stated on an average at 366,000 lbs. of metal. In fifty-six months, from 1809 to 1813, the total products of the mine and manufactories were 1,419,425 lbs. of mercury, 70,225 lbs. of cinnabar, 270,029 lbs. of vermilion, 2,450 lbs. of corrosive sublimate, 6,400 lbs. of calomel, and 2,867 lbs. of *red precipitate.*

The works were set on fire in 1803, and the only method of subduing the flames was by inundating the whole works with water; it was not till a twelvemonth had elapsed that this was pumped out, and the works carried on again.

There are upwards of 700 persons employed, who from the great heat of the mines, and the unwholesome effluvia of the mineral, suffer very severely in their health; they soon lose their teeth from salivation, and are subject to paralysis, convulsions, and premature old age: indeed, the district is said to be affected to a great extent, and near the town, cattle cannot be reared, and neither fruit nor grain will ripen: the inhabitants are universally afflicted with tooth-ache, and few survive forty years of age. The miners become so impregnated with mercury, that a piece of brass, put in their mouths, or rubbed between their fingers, becomes white like silver, and the metal has been known to exude from the pores of the body, when the men are in a profuse perspiration.

Criminals, and persons accused of political offences, are sent to work in these fatal mines, for a punishment.

In 1829, 636,000 lbs. of mercury were imported into Britain, of which 5510 lbs. came from Germany, 574,140 lbs. from Spain, 56,140 lbs. from Gibraltar, part of which came from Carniola, and

part from the Spanish mines: of the whole quantity, not a fourth was retained for home consumption.

The weight and fluidity of mercury particularly adapt it to two very important purposes, the construction of the barometer and thermometer.

If a fluid be poured into a tube, closed at one end, and the other be stopped with the finger, to confine the fluid, while the tube is being inverted, and its open end dipped into a vessel containing the same fluid, that portion in the tube will not run out, as might be expected, but will remain in the tube, standing at such a height in it, that this quantity of fluid will be exactly of the same weight as a column of air (another fluid) of the whole height of the atmosphere, and of the same diameter as the tube.

Now as this diameter remains the same, if any alteration should take place in the weight of that column of air, the fluid in the tube will rise or fall in it, so as exactly to counterbalance the new weight of air: consequently the changes in the height of the fluid in the tube will indicate the changes that take place in the weight of the atmosphere. Such an instrument is called a Barometer, from Greek words, meaning *measure* and *weight*.

If water were the fluid employed, the tube must be *thirty-two* and a half feet long, at least; for it

requires a column of water of that *length* palace one of air, of an equal diameter *or* are base. But mercury being thirteen and *a* times heavier than water, a column of *this metal* need only be twenty-nine inches long to *produce* the same effect, at the usual, or average, *weight* of the atmosphere. Hence, by employing mercury, barometers are made of a portable size, added to which the mercury is not subject to freeze, or to corrupt, as water would under similar circumstances.

The fluidity of mercury causes it to indicate changes of temperature, by expanding or contracting perceptibly to the eye, especially if enclosed in a narrow tube, closed air tight, and having no air in it: for, in this case, the expansion or contraction of the enclosed metal can only take place in the direction of the length of the tube, and is therefore very apparent: the Thermometer is such an instrument, and is so called from Greek words meaning *heat* and *measure*.

So essential are these two instruments to the prosecution of all scientific researches, that without them little or no progress could have been made, and we should still be in a state of ignorance on most subjects of natural philosophy.

Except for the above-mentioned purposes, mer*ury, in its* metallic form, is not much used in the

arts, but its salts and oxides are of the greatest importance in medicine.

A fulminating powder is prepared from mercury, analogous to that from platinum, gold, and silver, but less formidable, especially than that from silver. This fulminating mercury is now generally and extensively used for priming fowling-pieces, and other fire-arms: for this purpose, it is mixed with fine gunpowder, since the necessary charge of the powder, if used alone, would be too small to be manageable. The proportion of this mixture is three parts of the mercurial preparation to 600 of the gunpowder; the proper charge is enclosed in small copper caps, which are made with great rapidity, by a fly-press. There is a large manufactory of these percussion caps, at Jory near Paris, where 200,000,000 have been made in a few years.

Other powders are also used in percussion locks, as will be mentioned in a subsequent place.

Section 5. LEAD.

LEAD is of a bluish-grey colour, its specific gravity is 114, or nearly 11½ times heavier than water: it is soft and easily melted, its fusing point being as low as 594° of Fahrenheit's scale: when melting it possesses great lustre, greatly resembling mercury, but, having a strong affinity for oxygen, it soon

becomes tarnished on the surface, and in a short time is covered with a spongy oxide: when cold and scraped clean, it acquires a slight coating of oxide in a few hours, but subsequently undergoes no further change.

It unites with oxygen in different proportions, and forms.

1. The oxide above mentioned, as forming on the melted metal: this is called *litharge*, and is used in the manufacture of flint-glass, and in the glazing of earthenware,—lead, in most forms, being a powerful *flux*, or having the quality of accelerating the fusion of all substances which form glassy matter when melted: thus flint, which is not fusible alone, even in the focus of the most powerful lens, is easily melted when combined with lead.

2. A yellow oxide, called *massicot*, used in painting and in medicine.

3. White-lead is a combination of the yellow oxide, and carbonic acid: this carbonate of lead, so important from its use in painting, enamelling, &c., is manufactured in the following manner.

Sheets of lead are rolled up in loose rolls, so as to surround earthen pots, filled with vinegar, or *acetic acid*; a flat plate is put on the top of each roll; a series of these rolls are placed on dung, or tanner's bark, and then covered over with the same material; when another set of rolls and pots are

placed on the top of the former, and so on, till a stack containing several tons of lead is formed. The vinegar being heated by the fermentation of the dung or bark, is decomposed, and the carbonic acid of it unites with the lead.

The metal is kept in these stacks for six weeks, or two months; the pile is then taken down, and the brittle, hard salt, or the carbonate of lead, which is found coating the rolls of metal, is separated by rolling the lead, and is dried in stoves, and ground fine.

3. *Minium*, or red-lead, is another oxide of lead, and is also used in glass-making, enamelling, and many other arts.

Lead is the softest of all the durable metals; it can be scratched with the nail, and is easily cut by a knife; it marks paper with a bluish stain; it has little taste, but a perceptible smell on being rubbed.

The elasticity, ductility, and tenacity of lead are comparatively low; it cannot be drawn into wire thinner than a line in diameter, and even of that thickness, with difficulty; a wire of it, $\frac{1}{12}$ of an inch, will not support more than 20 pounds, and it would require one of 2½ inches to support a hundred weight.

Lead is very malleable, and can be hammered into thin leaves, but these are easily torn and split, from its *imperfect* tenacity.

The salts of lead are numerous and important; *acetate of lead*, or the oxide united with acetic acid, is called *sugar of lead*, and is used in medicine and in dyeing: and another combination with the same acid, is the basis of the dangerous cosmetic, called Goulard water.

All the salts of this metal are poisonous in a high degree, and from their sweet taste, are used by unprincipled wine merchants, to correct or conceal the acidity of liquors, when passing from the vinous into the acetous fermentation. This adulteration may be detected by means of the following liquid.

Dissolve 120 grains of sulphuret of lime, and 180 grains of super-tartrate of potash, in 16 ounces of distilled water, by repeated shaking; when perfectly dissolved, leave the mixture to settle, and pour off the clear liquid into clean phials, adding about twenty drops of hydrochloric acid to each. A small quantity of this test poured into a wine-glass of the suspected wine, will detect the presence of the smallest quantity of lead, by causing a black precipitate.

Small quantities of sugar of lead are used as a styptic against internal hemorrhage.

Lead unites with many metals, forming important *alloys*; one of the most so is that used in type-*founding, and consists* of lead and antimony, in

different proportions: this alloy is solid, malleable, harder than lead, and very fusible.

Solder, used by plumbers, is an alloy of one part tin with two of lead; it is malleable, and more fusible than tin; if solder be heated to a red heat, it takes fire and burns, and becomes converted into a white oxide, used in enamelling.

Thin plates, which line the chests in which tea is imported, are formed of an alloy of nine parts lead and one of tin.

An alloy of eight parts of bismuth, five of lead, and three of tin, forms *fusible* metal, (see BISMUTH): if a small proportion of mercury be added, the alloy is rendered still more fusible, and is employed for injecting into the blood-vessels, &c., in anatomical preparations.

A small proportion of lead, only one part to 1920 of gold, renders the metal as brittle as glass, a similar effect is produced with platinum and silver.

In consequence of the facility with which many acids dissolve lead, vessels of this metal should never be employed for containing liquid articles of food. It is said that the cyder of Devonshire is unwholesome, from its being put in lead cisterns to correct its acidity.

House-painters, and all mechanics who use lead oxides largely, are early in life liable to paralytic

affections, from the poisonous quality of the metal, of which they unavoidably inhale some in breathing. Formerly, when ladies made use of ceruse, a preparation of white-lead, their health was frequently much injured by the practice.

An amusing experiment is made, by suspending a small piece of zinc in a bottle, containing a saturated solution in water of acetate of lead: the affinity of the metals causes the lead to be deposited on the zinc, in minute particles, which assume very fantastic forms; and, from a fancied resemblance, the mass is called the *tree of Saturn.*

Other metals, treated in an analogous way, produce similar results; but none is so easily and so cheaply obtained as this.

Lead has been known from the earliest ages, and is frequently mentioned in the Mosaic writings.

It is next to iron the most abundantly diffused of all metals.

There is little or no lead found native, but some is said to occur in small masses, in the lava of the island of Madeira.

Its ores are numerous; principally containing sulphate, carbonate, phosphate, chromate of lead, *&c.: but the* most abundant, and most valuable, is

that termed *galena* or *lead glance*, which is a sulphuret of lead, or lead combined with sulphur, and also some other matters, frequently silver. This, next to pyrites (see IRON and COPPER,) is the most common of metallic ores. It is found in beds and veins in mountains and many rocks, in most countries. It is of a metallic lustre, greatly resembling the pure metal itself, easily cut and broken, but is not malleable; and occurs in masses of all sizes and figures, and often crystallized in cubes, and all its derivatives. It melts easily; it is so rich in metal that of 100 parts, from 54 to 85 are lead, 5 to 13 sulphur, and the rest oxide of iron, silver, gold, or other substances. One species of sulphuret of lead, found at Freyberg, contains lead, silver, antimony, iron, sulphur, alumina, and silica.

One ore of sulphuret of lead, contains so much sulphur as to burn on being held in the flame of a candle.

In our own country, lead is one of our most important and abundant metallic produce. There are lead-mines situated in Cornwall, Devonshire, Somersetshire, Derbyshire, Durham, Lancashire, Cumberland, Westmoreland, Shropshire, in several Welsh counties, and in Scotland and Ireland; and galena is the common ore in all these.

The metal is obtained in the following man-

ner: the ore, when brought up out of the mine, is dressed by women and boys, who, by means of a hammer, break off the impure and foreign matters that adhere to it; the galena is then broken into pieces of the size of a hazle-nut, and when washed from the clay and dirt, is ready for smelting.

This is performed in a common reverberatory furnace*; a ton, or more, of ore being spread on the floor of this, and soon brought to a red heat, by means of the flame from pit-coal, the ore is occasionally stirred with rakes, to expose fresh portions to the action of the flame. The mass, in a short time, begins to assume a pasty consistence; the heat is then lowered, so as to keep the ore at a dull red, till the sulphur is nearly all got rid of.

The fire is then increased again, till the mass is in perfect fusion, and consisting of two fluids; the lower metallic lead, and the upper a *slag*, containing still a good deal of lead, but mixed up with other matters. The fire is now damped, and a few spades full of quick-lime are thrown into the mass; this suddenly solidifies the slag, which is raked on one side, and the lead drawn off, through a tap-

* A reverberatory furnace is one arched over in such a way, that the flame of the fuel is reflected back, as it were, down upon *the metal*, or substance, put into the furnace, instead of rising up *the chimney at once.*

hole, into moulds; where it hardens into oblong masses, called *pigs*, weighing 60 lbs. each.

When the metal is drawn off, the slag is replaced in the bed again, the fire raised to a glowing red heat, which again melts it, and a new portion of lead is drawn off, as before. The refuse, though still containing 8 per cent. of lead, is now rejected, as not worth further trouble, and is used for mending the roads and other purposes.

Sixty-six per cent. is about the average produce of metal from the ore at the Derbyshire lead-works.

When the galena is known, or has been found by analysis, to contain a sufficient proportion of silver to make it worth extracting, the process is more complicated. The lead is then melted in a reverberatory furnace, and drawn off in the manner above described, only the scoriæ, or slag, is subjected, again and again, to increased heat, to obtain every particle of metal, the whole of which is received into a hemispherical reservoir adjoining the furnace. In this the lead is covered over with pounded charcoal, and remains untouched for some time, in order that the impurities may rise to the surface, where they are skimmed off; the fluid lead is then covered with saw-dust and chips of wood, to which resin is added by small pieces, the *melted metal* being all the time stirred about, to

assist its purification. The lead is then removed with iron ladles, and poured into moulds.

The next step is *refining*, or the process for separating the silver from the lead. The level floor of a reverberatory furnace is covered with a mixture of wood-ashes and sand, well beaten together, and formed into a shallow hollow in the middle, called the *Cupel*. On one side of the cupel an aperture is made, through which the oxidized lead may flow as it forms; and opposite is another for the admission of a current of air: in the top of the furnace is a circular aperture, corresponding in size with the cupel, and closed with a frame-work of iron, filled up with bricks.

The cupel is lined with hay, and filled with lead, in bars, or pigs, let down through the aperture just mentioned, which is then covered up, and the fire lighted. In about six hours the lead is entirely melted, and brought to a full red heat; a blast of air is then introduced through an iron pipe, so directed as to strike on the surface of the fluid metal; the ashes of the hay and other impurities are raked away by a wooden rake, thrust through the hole made for the *litharge*, or oxide; the first oxide, formed on the surface by the current of air, is scraped off, and this operation is repeated *five or six* times before the true litharge begins to form.

As soon as this takes place, the heat is increased, and the action of the blast, with a little assistance from the workman, forces the litharge, as it forms, through the proper aperture. A great deal of the lead being volatilized in the heat, and the furnace filled with vapours, an experienced eye alone can see what is going on in the cupel.

In about forty hours, the contents of the cupel being diminished to about a twenty-fifth of the original quantity, the litharge that now comes off is kept separate from the rest, because it contains some silver. As soon as the litharge ceases to form, the fire is damped, and the metal suddenly cooled, by water being poured on it. This cake of metal, left in the cupel, is silver, but not quite pure; it is again subjected to a similar process, in a more powerful furnace, to get rid of the lead still alloying it, and is then cast into ingots.

The *litharge*, or oxide of lead, is reconverted into metal, by melting in a furnace as before. The heat drives off the oxygen, and the lead which is obtained is much purer and softer than that from the common process.

In England the process of *refining* differs a little from that just described, which is the mode practised on the Continent. The difference consists principally in the cupel being made detached, of well-*burnt bone*-ashes, rammed into an iron frame, and

put separately into the furnace; the lead is introduced melted, and a fresh supply added, as it diminishes in quantity. But the general principle being the same, the method does not require more minute description.

The lead-ores of our northern mines contain only eleven and a half ounces of silver per ton; that of Huelpool in Cornwall, yielded sixty ounces. One ton of the ore of South Hoo mine, near Beralstone once yielded 135 ounces of pure silver.

Lead in sheets is used for covering the roofs of buildings, for making cisterns for water, vats for dyeing, &c., for coffins, and also for making pipes, gutters, and many other purposes.

Sheet-lead is formed either by *casting* or *rolling*. A strong table, from fifteen to twenty feet long, and five or six broad, is made with a ledge round it rising everywhere an equal height above it. The top of this table is covered with fine sifted sand which is spread smoothly over it, by being worked with a kind of trowel till equally dense everywhere, and then finished by a wooden ruler, called a *strike*, being drawn over the sand, and guided by, or resting on, the raised ledges. The ruler is so constructed as to leave the surface of the sand quite smooth at a small distance below the ledge, by *which the melted* lead, when poured upon the *sand, is confined.*

The melted metal is drawn from the furnace into a large iron vessel, which is raised by a crane, and tilted over, to cause the lead to run on the sand as rapidly as possible. Another strike is then drawn over the surface, which, by resting on the ledge, pushes forward the superfluous metal, and leaves a sheet of it, of an uniform thickness, equal to the height of the ledge above the sand. The superfluous metal removed by the strike is forced off the end of the table, into a vessel placed to receive it.

Rolled, or *milled* lead, as it is called, is made by passing a thick plate of cast lead between large rollers, till it is reduced to a given thickness, which varies according to the use the sheet-lead is to be put to, from about 7 lbs. to 12 or 14 lbs. to the square foot. Milled lead is of a more uniform thickness and density than cast sheet-lead, and is therefore used for the better kind of work.

Pipes of lead are either made by bending a strip of milled lead round an iron mould, or *core*, and soldering the edges together; or else, when of a smaller diameter, in the following manner:

A cylinder of lead, five or six inches in diameter, is cast with a small hole through its axis: a smooth iron rod, about fifteen feet in length, and of the requisite diameter, called a *triblet*, is forced through the

hollow lead tube; this is then drawn forcibly through a series of holes in iron plates, till the lead cylinder is extended over the whole triblet, which being withdrawn leaves the lead pipe of an equal bore.

The Chinese make the thin lead with which their tea-chests are lined, in a very simple manner. The melted metal is poured on a large flat stone, and another stone is immediately laid on it, which presses out the lead into the thin sheet, and cools it sufficiently to allow of its speedy removal, so that another casting may be proceeded with. The sheets are trimmed square, and afterwards soldered together.

Section 6. Palladium.

Palladium is of a bluish white, with a specific gravity of 113. It is both ductile and malleable, though less so than any other metal possessing those qualities, except Cadmium. In hardness it equals Tungsten, and in that quality these two metals surpass all others.

Palladium, having but little affinity for oxygen, undergoes no change by exposure to heat and air, and only fuses at a temperature a little below that of *Platinum*. It has been alloyed with other metals,

but from the scarcity of Palladium, only one of these alloys has been ever employed, and that, as far as we know, in only one instance, namely, in a strip of alloy of gold and palladium, let into the outer rim of the mural circle, at the Royal Observatory, Greenwich.

Palladium was discovered in 1803, by the late Dr. Wollaston, in crude platinum; these two metals being found in a native alloy, and the first also native in the same veins. The name was given from the planet Pallas, which had been recently discovered.

Section 7. Silver.

The white colour of this metal is too well known to require description. Its specific gravity is 105, being inferior in weight to platinum, gold, mercury, lead, tungsten, and palladium, but heavier than copper, iron, and all others.

In air and water, silver does not absorb oxygen, but if exposed to long-continued heat, in an open vessel, it may be converted into a greenish oxide. It is, therefore, in this respect, inferior to gold and platinum, though it ranks as one of the noble or precious metals.

Silver is tasteless and void of smell; it is more elastic than gold, and in malleability is second only

to that metal: it may be beaten out into leaves of only 100,000th of an inch in thickness. A vessel, capable of holding an ounce of water, may be made of a grain of silver. In tenacity it surpasses gold, though it is inferior to iron, copper, and platinum, (see PLATINUM.) A silver-wire, one-tenth of an inch in diameter, will sustain a weight of 250 lbs. It melts at a temperature of about 1000 degrees of Fahrenheit's thermometer, and is also more easily volatilized than gold, platinum, and some other metals.

The solar rays transmitted through a *lens* of thirty-three inches in diameter, volatilize gold and silver, converting them into a vapour, which rises to four or five inches; a piece of either metal, exposed within this limit to the smoke of the ore subjected to this intense heat, becomes plated or gilt over with a surface of the metal thus evaporated. It is remarkable, in this experiment, that the globules of the metal, as they first melt, turn rapidly round; this was supposed to be caused by the mechanical force of the rays of light; but as the effect is only observed with some, and not all metals so acted on, the real cause of this motion is still unknown.

Silver unites or alloys with many metals.

It is soluble in nitric, and, when heated, also in *sulphuric, acid.*

Silver has been known from the earliest ages.

It is found in ores of many kinds, and also native, or in the metallic state, but far from pure. The ores are found in veins in mountains, and they contain the metal united with others, especially antimony, arsenic, and lead; or else mineralized with sulphur, muriatic and sulphuric acids, &c. It is never found, like gold, in sand and alluvial soils, as washed down by streams.

Native silver crystallizes in cubes and octohedrons; but is also, and more commonly, found in irregular masses, often of considerable size. In 1750, a mass of silver, weighing one hundred weight and a quarter, was found in the mine at Himmels-fürst, in Saxony, and another equally large, again in 1771. In 1478 a rich vein of silver ore was discovered at Schneeberg, in Saxony, and so large a mass of native metal was cut out, that it served as a dining-table to Duke Albert, who descended into the mine to visit it; when smelted it yielded 44,000 lbs. weight of metal. Another mass of native silver, 600 lbs. in weight, was obtained from the Swedish mine of Köngsberg.

Native silver is commonly alloyed with either gold, copper, arsenic, or iron; the first compound is rare, but contains a great deal of gold.

Silver-ore, properly so called, is rare in England, but *our lead-ores* often contain a great deal of

the metal; so much, in some cases, as to be worth extracting, as is done in Wales, Yorkshire, Durham, &c. Indeed, many lead-ores in these counties contain a larger proportion of silver than the present average ores in Mexico and Peru.

Many years ago, a vein of silver was worked in Stirlingshire, which yielded from 40,000 to 50,000 pounds' worth of silver before it was exhausted.

At present, Cornwall and Devonshire yield the richest silver-lead ores, but there is comparatively little of them. The Ben-Alsten mine, in the latter county, has yielded a considerable quantity, seventy ounces having been obtained from each ton of lead; and another mine, near Truro, contains an ore which yields as much as 100 ounces to the ton of lead. In short, all lead-ores contain more or less silver; but, at present, in this country, they would not repay being worked for the precious metal, it being computed that fifteen ounces must be obtained from each ton of ore in order to do so; and the claims of the Crown on mines of precious metals, to the first offer of purchase, would still further reduce the profits. The exact quantity of silver now obtained, in our own island, is not accurately known; it is but trifling.

The mode of reducing the silver from the lead-ore is described under LEAD.

On the continent of Europe, besides France,

Spain, and Sweden, (where silver ore exists, but is not mined for at present in any great quantities,) Saxony possesses silver-mines of considerable extent, near Freyberg; a district celebrated for its mineral riches, and for the variety and magnitude of the mining operations carried on there. Werner, a celebrated geologist of the present century, founded a school for that science, at Freyberg, which holds a high rank.

The mines of Schemnitz, in Hungary, already mentioned in the account of gold, are equally productive of silver, which is obtained at the rate of four to five ounces from every hundred-weight of ore, consisting of masses of quartz, filling a vein which traverses a clay-rock. Two of the three principal veins yield most silver, while the gold is the principal produce of the third, in some parts of it.

At Kremnitz, in the same country, mines of gold and silver have been worked for at least a thousand years, in veins of a mountain of solid white quartz, containing silver-ore, yielding also gold; the veins are extended beyond 160 fathoms below the surface.

The first steam-engine ever used in Hungary, was erected by an Englishman in the emperor's service, in 1725, at Königsberg, which is also a gold and silver mining-district.

Joachimsthal, in Bohemia, has long been cele-

brated for its mines, situated in steep, rugged mountains, intersected by deep valleys, which allow of numerous *galleries* to the various works being opened in their sides: one *level*, by which the mines are drained, runs 34,000 feet, and is 1140 feet below the top of the mountain, but, in some places, operations have been carried on to the still greater depth of 2100 feet; and, in 1774, were, next to those of the Tyrol, the deepest mines in the world*. The produce of the Bohemian mines altogether, is stated to be only about 1920 ounces annually; but this arises rather from the works being neglected, in consequence of the superior richness of the Hungarian mines, than from any deficiency in the ores of Bohemia.

Sweden and Norway possess fertile mines. From those at Köngsberg, in the latter kingdom, large masses of native silver have been obtained; the annual produce is about 5000 lbs. weight of this metal. One mine, at Köngsberg, is 2250 feet deep.

It has been remarked, as a singular fact relating to the two metals, that while gold is most abundant in tropical countries and in plains, silver is most abundant in cold climates; and when it occurs in hot ones, it is always found on the sides of lofty

* *The perpendicular* depth, to which the deepest known mine *hes, is only 2765 feet,* or a little more than half a mile.

mountains, or in elevated regions, where the temperature is very low; but this is only true *generally*.

Silver abounds in the Altai mountains of northern Asia. The most important mines, those of Kolyvan, produced, from 1700 to 1794, about 1,300,000 lbs. of silver, and 40,000 lbs. of gold. Little or no silver is found in Africa.

But America is the country most productive in silver as well as in gold, the distinction above noticed being observable; the latter metal is found in the low lands of Brazil, &c., while all the silver-mines are in the regions of great elevation, and consequent cold, in Mexico and Peru.

The mines of Huantajaya, in Peru, furnish annually from 70 to 80,000 marks* of silver, derived either from native silver found in large masses, from muriate of silver, or from sulphuret and other ores.

The mines of Gualgayoc are situated fifty miles from Truxillo, and are 12,000 feet above the level of the sea. Silver in large masses is found there.

The mines of Potosi have been long celebrated as surpassing all others. These mines are in a mountain of that name, near the source of the river Plata (*Silver*), which derived its appellation from this circumstance.

This mountain, one of the most considerable in

* The mark is eight ounces troy.

the country, is of the form of a sugar-loaf, six leagues in circumference, and 4200 feet high; it is filled, from top to bottom, with veins of silver-ore, of the richest quality; and the whole mountain is perforated in every direction by the galleries excavated in the pursuit of it.

Its riches are said to have been discovered by accident. A Peruvian, chasing some Chamois among the rocks, laid hold of a small shrub in his ascent; it gave way, and disclosed an immense vein of silver, since called *la rica*, or "the rich." The Indian kept his discovery a secret, and only had recourse to it to supply his wants; but the improvement in his circumstances attracting attention, his companions drew the secret from him, and revealed it to their master, a Spaniard. The mine was, in consequence, immediately opened, and formally registered, according to the laws of the government, on the 21st April, 1545. Since that time it has been wrought constantly; and the silver which has openly paid the royal duty, has been valued at 234,700,000*l.* sterling.

The mountain is now completely excavated: it is perforated by above 300 pits, few, however, exceeding seventy yards in depth. At the base there are numerous galleries, called *sacabouas*, six feet high and eight broad; the air in these places is cold and unwholesome, yet the Indian miners,

SOUTH AMERICAN SILVER MINE.

who work in them alternately night and day, are entirely naked, to prevent the possibility of embezzlement.

Since the first discovery, the ore has materially deteriorated in quality, the best having been earliest exhausted; at present it is inferior in productiveness to that of many other mines. It has diminished in fertility in the proportion of 170 to 1; and the quantity of silver obtained from the mountain has diminished in the proportion of 4 to 1.

The Mexican mines are now the most productive on the western Continent. There are thirty-six mining-districts, comprising no less than 500 places celebrated for their silver-mines, which are about 3000 in number, and contain from 4 to 5000 beds, or veins, of ore. The produce from these mines has been gradually augmenting during the last century, and its annual value is estimated at about 4,830,000*l.* sterling, only one-twentieth of which is in gold. A considerably larger quantity might be obtained if better systems were practised, but the art of mining in Mexico is still excessively rude and unscientific; though since the year 1816, speculators from England have introduced some improvements, particularly steam-engines, for pumping out water, and for raising the ore.

The mine of Valenciana, the most famous of the Mexican mines, extends more than 3100 feet below

the surface; and the mine of Yauricocha is now the richest in Peru. The largest metallic vein of this, or any other metal, is one in the Andes, which is supposed to be 300 miles in length.

All the silver-mines of America, furnish annually about 7,241,936*l.*; all the European silver-mines, only 564,600*l.* sterling.

It has been calculated that 20,640,000*l.* sterling worth of gold, and 352,480,000*l.* sterling worth of silver have been drawn from the earth, during the whole period through which mines have been worked; yet this is supposed to constitute only one-fourth part of the value of all the metals which have been obtained*.

Silver, which is much more extensively used for coin than gold, is always alloyed, it being, in its pure state, too soft to be durable.

The alloy used in the silver-coinage of England consists of 11·1 parts of pure silver, and ·9 parts of copper.

A pound, troy weight, of the alloy is coined into sixty-six shillings, so that a *money* pound, of twenty shillings, contains 1745·454 grains of *standard* silver, of which 1614·545 are pure metal.

* The reader must again be reminded that all estimates of this sort are extremely uncertain, being made either from the *vaguest data*, or often from mere guess. In the account of Gold *some observations have* been made on this subject, to which he *may refer.*

A pound, troy weight, of standard gold (see p. 70) is coined into 46*l.* 14*s.* 6*d.*; a money pound of gold therefore contains 123·274 grains of gold, of which 113·001 are pure metal.

Hence in our present *currency* the value of standard gold is to that of silver as 14·159 to 1·, and of pure gold to pure silver as 14·287 to 1·.

In all countries of Europe the name *pound* was originally given to a quantity of coins containing a *pound* weight of silver; but through the cupidity or the necessities of successive monarchs, this standard of value has been departed from, and the name of pound has been given to coin of less weight, and of less purity. In England, where this practice has prevailed to a far less extent than in any other country, a pound *sterling* contains less than *one-third* of a pound *weight* of silver. In France, at the commencement of the Revolution, the *livre* contained only a *sixty-sixth* part of the silver which *nominally* it possessed; in Spain, the degradation has been carried still further.

Silver for articles of domestic use, furniture, ornaments, &c., is of about the same standard as for money.

Articles made of inferior metals are what is called *plated*, that is, covered over with a coating of silver, either by applying an amalgam of the metal, (see MERCURY,) and treating it as described

in the process of gilding, or by the following method.

Copper, alloyed with brass, is cast into ingots; these are filed perfectly smooth on the face, or faces, to be silvered over. A silver plate, the thickness of which is regulated by that of the copper, (the former being $\frac{1}{32}$ of an inch when the latter is $1\frac{1}{4}$ inch thick,) is cut rather smaller than the face of the copper to which it is to be applied, and scraped perfectly flat and clean; the two metals are then put and bound together with wire; and a saturated solution of borax is inserted round the edges, between the two faces. This substance, by fusing at a low heat, *runs*, and thus prevents the air from getting at, and oxidizing, the surface of the copper; an effect which would prevent the union of the two metals.

The ingot, thus prepared, is put into a proper furnace, and heated till the partial fusion of them causes the copper and silver to unite by their two surfaces; when this takes place, the ingot is immediately withdrawn, and is ready for rolling.

The rolling is performed in a mill, the ingot being annealed, or softened, in an oven, from time to time; for the pressure between the rollers condenses and hardens the metal so much, that it *would crack unless* this precaution were taken.

last rolling takes place between finely-polished

steel rollers, which give an even surface to the plate, the silver being equally spread over the expanded copper.

In all the better kinds of plated goods, made from this silvered copper, the prominent edges, which, being more exposed to rubbing, would soon wear out, and thus show the copper, are, to avoid this evil, made of solid silver. These parts are formed separately, and put on afterwards with solder.

Copper is plated to draw out into wire in the following manner. Pure copper is forged, and drawn into a cylinder about 18 or 20 inches long and $1\frac{1}{4}$ inch in diameter, and is scraped perfectly clean: the silver is formed into a very thin tube, one edge overlapping the other, and the tube being a little larger in diameter than the copper cylinder. Another copper cylinder is heated red hot, and, being inserted by one end in a hole, the silver tube is passed over it, and the overlapping edges are welded together, by rubbing them briskly, with considerable pressure, with a polished steel burnisher. The cylinder to be plated, which is two inches longer than the tube, is now put into this, and the ends of the silver are worked closely into a groove cut in the copper for that purpose, so as to exclude the air; the whole is now heated red hot, and the metals are made to unite by burnishing

the silver all over. The cylinder is then drawn out, in a draw-mill, into wire of the proper size and figure; this being given by the form of the holes through which the wire is forced, or by that of notches in steel rollers, between which it is passed. By this means wire is formed either flat, half round, fluted, &c., according to the articles, such as toast-racks, bread-baskets, &c., which are to be made of it.

Oxide of silver is employed to give a yellow colour in porcelain painting.

The brass dials of clocks, the faces of barometers and thermometers, &c., are *silvered* by rubbing them with a compound of chloride of silver, whiting and pearl-ash.

Steel, for surgeons' instruments, razors, &c., is found to be improved in quality by adding one five-hundredth part of silver to it.

Lunar Caustic, employed by surgeons for cauterizing, or *burning* away the diseased flesh in wounds, &c., is nitrate of silver; or a salt formed by dissolving silver in nitric acid. It stains the skin and all animal matter indelibly black, and literally *burns* it, by the tendency of the salt to recover the metallic form, by parting with its oxygen. Ten grains of lunar caustic, dissolved in gum-water, *make an excellent* marking-ink for linen, which is *never effaced by* washing.

The two most dangerous explosive compounds, called *fulminating powders*, are prepared from silver; one of them is so formidable, that a carriage passing along the street, by shaking the room, has been known to explode it; and it often explodes voluntarily during the preparation of it. A small quantity would be sufficient to destroy a house.

The other is less susceptible; of this, the detonating balls, sold as toys, are formed. In these, a particle of the compound, as big as the smallest pin's head, is sufficient to produce a sharp and loud report when the ball is thrown on the ground.

Section 8. Bismuth.

Bismuth is of a cream-colour, or a reddish-white Its specific gravity is 98. It is neither malleable nor ductile, but fuses at the low temperature of 476 of Fahrenheit. In hardness it is intermediate between gold and silver.

It does not oxidize when cold, but in a state of fusion a film forms on it. At a strong red heat, it takes fire and gives out a yellow smoke, which is another oxide.

It alloys readily with most metals, and these possess, by the union, an increased degree of fusibility, remarkably great in some cases. The alloy,

consisting of eight parts of bismuth, five of tin, and three of lead, melts at a heat below that of boiling water; though tin, the most easily fusible of the three components, requires a temperature more than double that of boiling water to fuse it.

The oxides of Bismuth form salts with many acids.

Bismuth was discovered in the early part of the sixteenth century. It is found native, in different forms, and crystallized, in the veins of mountains, accompanying the ores of cobalt, nickel, lead, and occasionally those of silver, in Saxony, Bohemia, France, Sweden, and Cornwall. It occurs also in other ores.

Bismuth enters into the composition of some kinds of pewter. Equal weights of lead and this metal form a brilliant white alloy, harder than lead, and tolerably malleable.

One part of Bismuth, with five of Lead, and three of Tin, form the solder used by pewterers: and it is also added to the composition for types.

Glass globes are *silvered* on the inside, by putting in them a small piece of an alloy, consisting of two parts bismuth, one lead, one tin, and four of mercury; this melts, on the globe being plunged in hot water, and by turning it round, the fluid alloy is spread over the inner surface.

Flake-white, and *Pearl-white,* are precipitates from solutions of salts of this metal, used as paints, and as cosmetics; and an oxide is occasionally used in medicine.

Bismuth enters into the composition of two *sympathetic inks;* characters written with which are invisible when dry, but appear again on damping the paper, or on holding it over vapour of sulphur. These inks are solutions of nitrate and hydrosulphuret of bismuth.

Section 9. URANIUM.

THIS is a grey metal, with a specific gravity of 90; it is not fusible in any furnace-heat, and in consequence of the difficulty of reducing it from the ore, but little is known of it.

Uranium was discovered, in 1789, by Klaproth, who found that the mineral called Pitch-blende was an ore of a new metal, which he named after the recently-discovered planet, Uranus.

There are only two ores containing it; both are found in Cornwall, in Saxony, and in a few other places.

Oxides of Uranium have been used in porcelain painting, and in the staining of glass, but otherwise it is unemployed in the arts.

Section 10. Vanadium

Is a recently-discovered metal, the properties of which are not yet ascertained; having been discovered in Sweden, its name was given from that of a Scandinavian deity.

The inutility of the last-mentioned metals, together with some others described in the preceding chapter, arises only from our ignorance of their qualities and properties. The time may come when they will be found available in arts yet uninvented; the history of Platinum would lead us to this conclusion; the first discoverers of that metal probably made a similar prediction, which we have seen gradually accomplished. Nor need we fear that any new application of a metal will be restricted by a paucity of it; minerals are rare only because they are unsought for, though, of course, many elementary principles must be more abundant than others, the least so, we may rely on it, exists in sufficient abundance to supply any wants we may feel.

Chapter VIII.

Section 1. Copper.

Copper, when pure, is of a red colour; its specific gravity is 89; or it is nearly nine times as heavy as water.

Both the smell and taste of this metal are excessively nauseous. It is very malleable, next so in degree after gold and silver, and can be beaten out into extremely thin leaves. In ductility it ranks after gold, silver, platinum, and iron; while in tenacity it only yields to iron. A copper wire one-tenth of an inch in diameter, will sustain a weight of 385 lbs.

Copper is the most sonorous of all metals; and is therefore employed for trumpets, and similar musical instruments.

Its fusing-point is 1450 degrees of Fahrenheit; and it can be volatilized by an increased heat.

Copper is not acted on by water at common temperatures, but, if long exposed to air and moisture, it oxidizes; as it also does in air alone, if heated to redness. It combines with oxygen in two proportions. Verdigris is the oxide formed by exposure to air and moisture.

Copper admits of a greater degree of condensa-

tion, by pressure or hammering, than any other metal.

The alloys of copper are numerous and important; it forms a part of the gold and silver used for coin, plate, ornaments, &c., as has been mentioned; but BRASS is the most important of the alloys of copper. Brass is produced by cementing copper-plates with *calamine*, an oxide of *zinc*, mixed with charcoal. This compound mass being heated, the two metals combine. If their union were attempted by simply fusing them together, the process would not succeed, since the heat necessary to melt the copper would volatilize the zinc.

The best brass is made in England by the following process. The raw calamine is first pounded, washed, sifted, and calcined; it is then mixed with three or four parts of charcoal: layers of this mixture are put alternately with bits of copper, or refuse pieces of that metal, into crucibles, which, when filled, are *luted* up, or closed air-tight. These crucibles are arranged on the floor of a conical furnace, and covered up with coal, and a fire is kept up from twelve to twenty hours; after which the heat is raised to such a point as to fuse the whole mass, and the brass, in a melting state, is *poured into moulds*. The proportions in which the *two metals* are combined to form brass, vary in

different places, from twelve to twenty-five of zinc to one hundred of copper.

Brass is more easily fusible than copper, more ductile, and equally malleable. Many of its uses are well known; besides being employed in making articles of domestic use, there is no instrument or machine, many parts of which, if not the whole, are not made of it. Whenever two parts of a machine *work* together, or in one another, it is found that *friction*, and therefore *wear*, is much diminished by their being made of different metals; and experience has shown that iron and brass are best adapted to this purpose. All the parts of steam-engines, and of large machines, which receive the axles, or centres of motion, of other parts, are hence made of brass, and astronomical and philosophical instruments are wholly composed of this alloy. Brass, by its ductility, is better adapted to the manufacture of wire, than any other metallic substance; in the making of pins brass wire is extensively used.

The compositions, known under the name of *Dutch gold, Pinchbeck, Tombac, Prince Rupert's metal*, &c., are only varieties of brass, differing in the proportions of the copper and zinc.

Bronze is a compound of brass, with a small proportion of tin, and, occasionally, of other metals.

An alloy of one part of tin with three of copper,

constitutes *Bell-metal:* and an alloy of copper with eight to ten per cent. of tin, is used for casting cannon. When bell-metal is used for making bells, zinc, antimony, and silver, are added, to improve the sonorousness of the compound.

The famous *Corinthian Brass* of antiquity was an alloy of copper with several other metals; it was said to have been produced accidentally, by the fusion together of various articles formed of these metals, during the destruction by fire of the city of Corinth, by the Romans. Pliny states, that vases made of this brass were considered more valuable than if made of gold, on account of the beauty of the metal, and its fitness for chasing and sculpture, or other modes of ornamenting.

Swords and cutting instruments, among the ancients, before iron was used for that purpose, were made of copper, alloyed with from one to five per cent of tin.

A mixture of two parts copper with one of tin, forms an extremely hard, fine, brittle alloy, admitting of an exquisite polish, with a lustre nearly equal to that of mercury; it is called *speculum metal*, from its being employed for the reflectors of telescopes, and similar optical purposes. This alloy generally contains a little zinc, arsenic, and silver: *it was known to the ancients, and used by them for making mirrors.*

The *White Copper*, or *Packfong*, of the Chinese, is, by some persons, supposed to be an alloy of copper, zinc, nickel, and iron; the copper being one-half of the whole, and the other metals in about equal proportions. It is white, hard, and malleable, and capable of receiving a high polish.

Copper, with about a fourth of its weight of lead, forms *Pot-metal*. It also contributes to the composition of pewter (see TIN.)

Many of the Grecian and Roman coins were formed of an alloy of 100 parts of copper, 2 of lead, and 2 of tin, or with a larger proportion of the latter metals. The union of copper and lead is, however, very imperfect, the latter metal often separating again from the alloy, by an application of a low degree of heat, sufficient to fuse it.

The compositions for imitating silver, called *German Silver*, &c., are alloys of copper of various kinds. That long used at Suhl, in Saxe Hildburghausen, in making spurs, and many other articles, was composed of 88 of copper, 8·75 of nickel, and 2·5 of iron, antimony, clay, flint, and other extraneous ingredients, which had not been separated from the ores.

Copper has been known from the remotest ages; it occurs frequently in the native state, either in *masses, grains,* or crystallized in cubes and octo

hedrons; and is found in veins and beds, in quartz, granite slate, limestone and other rocks, accompanied by various other ores of the metal, which are so numerous, that a collection in Cornwall contains 1000 different kinds. One species of copper-ore is the fine ornamental stone called Malachite; this is a carbonate of copper, the best specimens of which come from Hungary and Siberia.

The most abundant and most generally-diffused ore, and that from which the metal is chiefly obtained, is the *Sulphuret of Copper*, termed copper pyrites, (from the Greek word for fire,) composed of copper, sulphur, and a little iron.

In Britain there are mines of copper in Anglesea, Cumberland, &c., but the most extensive and richest are those of Cornwall and Devonshire; and, considering the wild and romantic country, the skill and activity of the workmen, with the extent and perfection of the machinery employed, in no country of the world does mining present itself under more imposing appearances than in this district.

The principal mines lie between the Land's End and Truro, and are concentrated in a few principal points, the most important being in the neighbourhood of Redruth.

There are three principal systems of veins or

lodes, which must have been formed at different geological periods; for since the one cuts and intersects the others, it must necessarily have been of more recent formation. The oldest and most extensive run nearly east and west, and *dip* to the north, at an angle varying from 35 to 70 degrees. Their depth is unknown, for in few, if any, cases, has a vein been worked out to its bottom; before this is attained the mine is generally abandoned, either from a deterioration in the richness of the ore, or from the increasing difficulty and expense of draining.

The second series of lodes, in respect to age, run from north-west to south-east; while the third again pursue an east and west direction.

The average width of all these veins is about a yard; when it attains two yards it is considered as large. In some places, however, veins have been worked which were twelve, and in one instance, thirty feet wide. In length they vary from one to seven miles.

There are upwards of eighty copper-mines in Cornwall, varying in their productiveness from one to 1900 tons of pure copper annually.

The Dolcoath mine has been carried to a depth of 1380 feet. Many of them have been worked beneath the bed of the ocean.

The Botallack mine, of which the opposite cut presents a view, is remarkable for its romantic and singular situation. It lies on the north-western coast of Cornwall, near St. Just; the entrance to the mine is in the rock, immediately overhanging the sea, and the works are carried for many hundred feet under the bed of the ocean. The roar of the waves during storms can be heard in the galleries beneath, producing a most appalling effect.

The most extensive system of mines in Cornwall are those called the "Consolidated Mines," near Redruth. They are situated on a range of hills 300 feet above the level of the sea; the deepest of the shafts reaches 1650 feet from the surface; and so numerous are they, that it is calculated their united length is nearly equal to twenty miles, while that of the excavated galleries, levels, &c., amounts to nearly forty-eight miles. These mines are kept free from water by means of nine large steam-engines; eight others, smaller, are employed for raising ore, &c.; and six water-wheels contribute their aid, besides horse-whins or cranes: this mass of machinery, it is calculated, is equivalent to the labour of upwards of 4000 horses. The annual average of copper obtained from the ore, is upwards of 1400 tons. The number of persons employed immediately in the various processes exceeds 2500.

Another copper-mine near Tavistock, in Devon-

THE BOTALLACK COPPER-MINE, CORNWALL.

shire, called Wheal Friendship, is deserving of notice here, on account of a contrivance, called an *inclined plane*, for raising the ore. This is a gallery or adit, about seven feet high and five wide, excavated into the hill for a distance of 650 yards; but instead of being horizontal, or only slightly inclined, as common day-levels are, it forms an angle with the horizon, of from thirty to forty-five degrees, which exceeds the accessible slope of any mountain or hill in any country. The furthest extremity of the plane is 1025 feet below the level of its mouth or entrance, (which is shown in the following cut.)

A single rail-road runs the whole length of the plane, and on this a rectangular wagon, made of cast-iron, is drawn up loaded with ore or rock, by means of a chain, passing over rollers, placed between the rails, and wound round a cylinder or *barrel*, worked by a powerful water-wheel, which is turned by a stream brought from a considerable distance for the use of the mine. When the wagon comes to the mouth of the plane, it is unloaded, and then allowed to run back again down the plane, by its own weight, a check being kept by the machinery at the barrel, to prevent the effects of the enormous velocity which a heavy wagon would acquire, if left to descend such a slope without this precaution. Accidents have occurred, causing the breaking of the chain, and the wagon thus left to

itself, when it arrived at the end, and struck against the rock, was reduced, by the concussion, to a shapeless mass.

Besides this inclined plane, and another similar and older one near it, the Wheal Friendship Mine has five or six pits or shafts, some exceeding 1000 feet in depth, and levels amounting in their united lengths to several miles; these being above one another, and communicating with the shafts at heights of about fifty to sixty feet. The water is pumped from this mine, by four other large water-wheels, the accumulation being so rapid, that it is necessary to raise from 700 to 800 gallons per minute, to keep the works from being inundated.

Besides those of our own country, copper-mines are worked in Spain, France, Austria, Transylvania, Prussia, Saxony, Sweden, Norway, Russia, and in Mexico.

The principal copper-mine in Sweden is the celebrated one of Fahlun, in the province of Dalecarlia. This mine is a vast chasm, formed by the artificial excavations for the ore, the bed of which is not above a mile in extent. The descent to the first gallery is by wooden ladders, and from thence by steps cut in the rock, made so commodious that horses ascend and descend, to bring out the *ore; at the* bottom of this first stage there is another *deep pit, the* descent to which is by ladders again.

INCLINED PLANE AT WHEAL FRIENDSHIP COPPER-MINE.

When Mr. Coxe visited the mine in 1795, the whole depth was about 1020 feet, and it took him four hours to ascend again to the surface.

It is said that this mine was worked before the Christian æra; but all that is certainly known is, that it has been so ever since the twelfth century. Dr. Clarke states that the place of descent is from a small lodge, guarded by sentinels. A few months previous to his visit, some thieves, who entered the mine, being disturbed, fled, leaving their burning torches: the timber-work caught fire, and this communicating to the pyrites, the conflagration has continued ever since, in spite of all attempts to arrest it, by stopping up the passages leading to the burning part. The fire was, however, permitted to continue to a certain extent, for the sake of the sulphate of copper which was obtained from the ore thus roasted.

The part of the mine open to the sky, is of a funnel-shape, resembling the crater of a volcano. It was originally a mine of the usual construction, but in consequence of the numerous galleries excavated, and sufficient attention not being paid to the propping up the roofs of these, the whole central mass fell in, in 1666, and thus formed the present open basin. A principal level is carried from the bottom of the crater; and other shafts and works sunk, so that the deepest part is upwards

There are stables in these subterranean places, for horses which never see the light of day; and there is a wainscotted chamber for the council to meet in. By an old custom, each king, on his accession to the throne of Sweden, visits the mine, and inscribes his name on the walls of this apartment.

The mode of reducing the ore as practised at the Paris mine, in the island of Anglesea, is as follows.

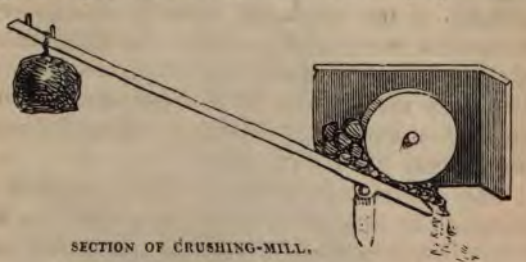
The pyrites, which is mostly obtained in large pieces, by blasting with gunpowder, is first broken into smaller, by women and children, with hammers; the ore is then put into a kiln, from which flues proceed, opening into a long, closed, pent-house gallery, in order to collect the sulphur that is sublimed. The kiln is covered up close, and the ore set on fire in a few places, which gradually spreads to the whole mass. The sulphur rises in vapour, and passes into the gallery, whence it is swept from the walls on which it settles. The mass of ore, when once kindled, continues to burn with a smouldering heat, for six months, the sulphur-chamber being cleared out four times during the period.

The richest part of the ore thus roasted is *exported at once*; the poorer is smelted on the *pot, in ranges of* reverberatory furnaces, thirty-one

being under one roof, side by side, in a row. They are air-furnaces, with high chimneys, causing a most powerful draught; the fuel is coal, and the flame passes over a mass of roasted ore, of twelve hundred-weight, spread on the bed of the furnace, and previously mixed with a small portion of coal-dust. The ore is by this means melted, and the metal, but very impure, drawn off into earthen moulds; half a hundred-weight of this rough copper is yielded by each charge of ore, and this takes about five hours to obtain.

But a better method of proceeding is employed in Cornwall, where the great capital devoted to the works causes every improvement to be had recourse to.

After the ore is broken by hand into small pieces, the richer portions, which are softest, are crushed in a kind of mill, of which the following figure represents a section. A *stamping-mill* is



SECTION OF CRUSHING-MILL.

employed to break the coarser and harder pieces; this consists of heavy hammers, or *stampers*, raised by cog-wheels, and suffered to fall on the ore, which is placed in a trough, through which a stream of water is constantly flowing; the ends of the trough being iron plates perforated with holes for this object. The finer portions broken, are by this means washed away into another vessel.

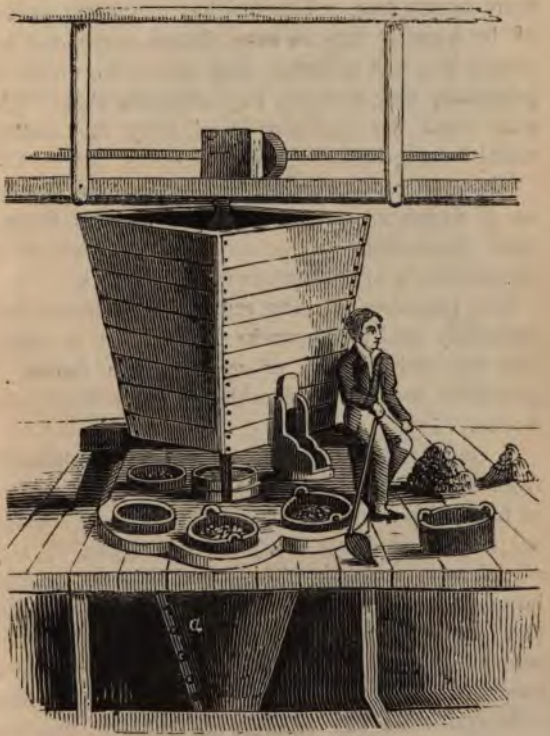
The next operation is called *jigging*, which used to be performed by shaking the pounded ore in iron-wire sieves, the bottom being kept under water, which caused the heavier parts, containing most metal, to sink to the bottom of the sieve, while the soluble earthy matter was either washed away, or remained in a stratum at top, and was removed by hand.

The cut opposite represents the machinery employed to obviate the use of manual labour in jigging, as erected at the Fowey Consolidated Mine, and one of the jigging-machines is shown on a larger scale in the following page. The pounded ore is put into the hopper-box, and a supply of water forced up through the holes in the bottom, by a kind of piston, which works in the vessel (*a*) immediately beneath the sieves.

The ore thus prepared for smelting, consists of copper, iron, sulphur, arsenic, &c., mixed with from 50 to 70 per cent. of earthy matter;

FOWEY CONSOLIDATED COPPER-MINE.

obtain the copper free from all these foreign substances, the ore is subjected to a series of alternate *roastings*, or calcinings, and meltings, varying in



JIGGING MACHINE.

number according to circumstances, but generally consisting of four calcinations, alternating with four fusions, the copper being each time obtained more nearly pure. The melting copper is drawn off by a gutter into an iron cistern, suspended by chains in a well of water; this causes the metal to granulate, and prevents any accidents that might arise from the explosion caused by the molten metal flowing into the water.

These operations for the better ores are carried on at Swansea, and other places on the Bristol coast, whither the ore is conveyed on account of the proximity of coal-mines to supply fuel.

The processes for the reduction of copper are extremely fatal to the workmen engaged in them, and the noisomeness of the metallic fumes is perceived for a considerable distance from the works.

A considerable quantity of copper is obtained from the springs which flow in most copper-mines, or from hills containing this metal. These springs are impregnated with *sulphate of copper*, or *blue vitriol*, as it is called. The water is pumped into large open pits, lined with clay, rammed hard, and two or three feet deep; into these a quantity of old refuse iron, of any kind, is thrown, and left for a *considerable time*. The iron, having a greater affinity *for the acid* than the copper, abstracts it, and the

latter metal is precipitated in a brown mud, which is raked out, dried in the sun, and then reduced in furnaces. Being very rich in metal, it is usual previously to mix it with poorer ores.

The total quantity of *fine* copper produced in Great Britain and Ireland, in 1829, amounted to 12,000 tons, of which nearly 8000 were exported. The average price of copper, for the last thirty years, has been 121*l.* per ton, but the price has been gradually falling for the last seven or eight. Of the total quantity produced in 1829, 9656 tons were furnished by the Cornwall mines alone.

Oxides of copper are soluble in most acids, and form salts; some of which are important in the arts.

Blue Vitriol is a sulphate of copper; it is employed in glass-staining, in dyeing, and occasionally in surgery, &c. It is prepared in England for these purposes.

The fine blue colour, called *Verditer*, is prepared from nitrate of copper.

Verdigris is the acetate of copper, and is prepared in large quantities in the south of France, by laying flat plates of hot copper alternately with the refuse of the wine-presses, called *marc*, first slightly fermented into the acetous state, for from ten to twenty days, in covered barrels. When these are opened, the plates are found covered with a green crust; this is

made to swell, and increase in quantity and quality, by damping and drying the plates, alternately, seven or eight times; the crust is then scraped off, and the plates again used, till they are entirely converted into the salt. Verdigris is used in painting, dyeing, &c.

The uses of copper are numberless. The bottoms of large ships are sheathed with it, to protect the timber from sea-worms, and to facilitate the motion of the vessel, by diminishing friction in the water; large boilers for sugar-works, brewing, &c., are made of copper; as are also domestic utensils, as saucepans, kettles, &c.

But, whenever a copper vessel is intended for the preparation of food, the surface ought to be covered with a coating of tin, or silver; for copper is easily *corroded*, or dissolved, by the acid contained in most articles of food, and highly-poisonous salts are thus formed, which would have fatal effects if taken into the stomach. Accidents are perpetually occurring from using copper vessels, the tinning or plating of which has worn off. In Sweden, the government does not, for this reason, allow of any culinary vessel being made of copper.

Another most important use of copper, for which its softness and malleability particularly adapt it, is *for engraving* on, for the purpose of multiplying *copies of any* design, by impressions taken on paper *rom a copper*-plate, on which that subject has been

engraved, or cut in, in lines. The copper for this purpose should be very pure, free from all defects, and well polished in thin plates. The surface being covered with a particular varnish, the outlines and lines for the shading are cut through this varnish, into the metal, by a needle or sharp tool: diluted nitrous acid being then poured on the plate, the varnish defends the general surface, while the acid dissolves the copper, where exposed to its action in the lines; this process is called *etching:* the varnish is then cleaned off, and the work finished by graving-tools. The lines thus engraved are filled in with a printing-ink, spreading it over the surface, and the plate is wiped with cloths, so as to remove the superfluous ink from the plane part of the face, but yet not to wipe out the ink from the lines. The impressions are taken by laying damped paper on the plate, thus prepared, and passing them through a rolling-press, which, forcing the paper close down on the plate, brings the ink out of the lines, and transfers the design to the paper.

Steel-plates are now made use of for the same purpose, from their superior durability; the process of engraving upon them is precisely the same as upon copper, only instead of nitrous acid, a solution of corrosive sublimate, or some other liquid of appropriate kind, is used in the process of etching.

Section 2. Cadmium

Is of a bluish-white colour, with a specific gravity of 86. It is the least malleable and ductile of all metals which possess those properties. It fuses, and is volatilized, at the temperature of boiling mercury. It is rather soft and flexible, crackling like tin when bent, but is harder and more tenacious than that metal.

Cadmium was discovered by Professor Stromeyer, of Göttingen, in 1817, in an oxide of zinc; and it has since been found in an ore of that metal, occurring at Freyberg, and in Derbyshire.

Its alloys, oxides, and salts, are only curious as chemical combinations. It has not, as yet, been employed in the arts in any form.

Section 3. Cobalt.

This metal is of a purplish-gray colour, and fibrous texture: its specific gravity is 85: it is a little harder than lead. It is only fusible at the high temperature of 16,677* of Fahrenheit. When

* The fusibility of the glass tube, and the volatility of the mercury, prevent us from being able to apply a thermometer of the *ordinary construction* to the measurement of temperatures above *5 or 600 degrees. An instrument* called a *pyrometer* is employed *for greater temperatures,* in which the expansion of small rods, of

heated it is partly malleable. Cobalt is permanently magnetic, like iron and nickel.

It oxidizes, at a red heat, in an open vessel. The fine blue mineral called *Zaffre* is an impure oxide of this metal, containing some silica, and is obtained from the commonest ore of it by roasting, which process dissipates the arsenic and sulphur contained in it. The colour of this oxide is so intense, that a grain of it will impart a full blue to two hundred and forty of glass.

Smalt, or *smaltz*, is a vitreous substance, pro-

a particular clay, is made the measure: but the law of expansion of this clay is not known, and varies according to circumstances over which we have no control, consequently all measurement of high temperatures is very difficult and uncertain; and such numbers as that in the text must only be considered as approximations, often very vague ones. It is only the temperature, *relative* to one another, at which different bodies melt, that require an intense heat to fuse them, that we can hope to obtain, and not the *degree* of their fusing-points, as referred to the scale of the mercurial thermometer. If we could put pieces of flint, clay, lime, platinum, uranium, tungsten, iron, cobalt, &c., of precisely equal weights, and *under exactly the same conditions in every respect*, in a furnace together, by observing the order in which they melted, an approximation to this relative temperature might be obtained: but for scientific precision, it would be necessary that all the substances should be perfectly pure, free from all other matter, and that from the time the first began to liquefy, the heat of the furnace should be kept to *precisely* the same intensity. If these conditions could be fulfilled, which unfortunately they cannot, the difference in the time that elapsed between the successive fusions of the bodies would afford a sort of scale to estimate the temperatures by.

duced by melting zaffre with silex and potash: when ground to a fine powder, it is known by the name of *powder-blue*. The colour of the oxide of cobalt is not affected by fire; hence smalt is of great use in the colouring of earthenware, staining glass, enamelling, &c., and in several other arts.

It is hardly necessary to remind the learner that *powder-blue*, being a *glass*, is insoluble in water; and that he must not therefore confound it with the *stone-blue* used by laundresses, which is indigo, a vegetable production.

Smalt is principally manufactured in Germany, Norway, and the Netherlands. Nearly 500,000 lbs. of it were imported into Britain from these countries in 1828.

Cobalt alloys with gold, platinum, tin, copper, iron, antimony, lead, and arsenic; with some of which metals it occurs naturally combined.

Cobalt was discovered, as a distinct metal, in 1733, by Brandt; but Zaffre had been used to colour glass from the year 1540, when it was first applied to that purpose by Schurer, a glass-maker in Germany.

The name of the metal is a corruption of *Kobold*, the German term for an imaginary being, supposed to preside over mines, and troublesome to miners, which, before its uses were known, was the case with this metal.

It is not found native, but there are several ores of it, which occur in Norway, Sweden, Cornwall, and other parts of Britain. The commonest is the white cobalt.

An oxide of cobalt, dissolved in muriatic acid, forms a sympathetic ink; the characters written with it on paper, are invisible when cold, but when warmed they become of a bright green, which colour they lose again on cooling; and this may be repeated several times. This ink is obtained by digesting zaffre, for some time, in nitro-muriatic acid, with a moderate heat.

Section 4. Arsenic

Is of a grey colour; its specific gravity is 83; and it is nearly as soft as lead. Arsenic is readily fusible, and is volatilized at a temperature of 356 degrees: if thrown on hot iron, it burns with a blue flame, and a dense white smoke, and emits a powerful odour of garlic.

It combines with oxygen in two definite proportions, forming two acids, called arsenious and arsenic acid.

Arsenic combined with sulphur forms *realgar* and *orpiment*, which are found as natural ores; the former is of a beautiful variable red. It is met with in metalliferous veins, and in the neighbourhood of volcanic mountains.

Arsenic forms alloys with all other metals; even in very small quantities it renders them brittle and destroys their malleability, and hence it is necessary, during the reduction of their ores, to free metals from this troublesome ally. These natural alloys of arsenic with other metals are numerous, but, fortunately, the property of easy volatilization, as has been mentioned in describing the process of obtaining metallic copper from the ore, admits of easy separation.

Arsenic, in its pure metallic state, has little effect on the animal system; but, when combined with oxygen it becomes a virulent poison. One chemist was killed by merely inhaling, during an experiment, a small quantity of a gas formed by a combination of arsenic and hydrogen.

The arsenic of the shops is the white oxide of the metal, or *arsenious acid;* and daily experience of its fatal powers is afforded by the wickedness or folly of mankind.

This white oxide is more readily soluble in water than any other oxide of a permanent metal, and the solution is clear, colourless, and has an acid, warm, metallic taste. When administered in small doses it is, in certain cases, a medicine of great efficacy.

The ancients employed a sulphuret of arsenic as *a medicine* and as a paint; Aristotle called this *mineral, sandarache.* The word arsenicon was first

used by Dioscorides and others, at the beginning of the Christian era; this word means *masculine*, and the name was conferred on the mineral on account of its powers. It was not till 1733 that the true metal was obtained from the white oxide, and investigated by Brandt.

Arsenic exists native as a greyish, black, dull substance, externally; and of a lead-grey, inclining to tin-white, inwardly; and what is singular, though its form is irregular, yet, internally, *cavities* are found in it of the forms of cubes and octohedrons. It occurs in veins of mountains in several localities in Europe, accompanying ores of silver, cobalt, copper, &c.

The white oxide, the bright red sulphuret realgar, and the bright yellow sulphuret, orpiment, are its principal ores.

Preparations of this metal are used in medicine; and pigments, such as King's-yellow, are used in colouring glass, &c., as are also the common white oxide; but glass prepared with it, in large quantities, ought not to be used for domestic purposes.

Its alloy with copper is used in speculum-metal. (See COPPER.)

Lead, for shot, is also alloyed with arsenic; but it is, on the whole, one of the least useful to man of all the metallic substances which he employs.

Section 5. Nickel

Is nearly as white as silver, with a slight yellow cast: its specific gravity is 83. It is both ductile and malleable, though less so than even lead. Its fusing-point is 21877 of Fahrenheit, while that of iron is only 17977: it is rather softer than this last metal.

Nickel possesses the rare quality of magnetism in a very considerable degree; its energy in this respect being to that of iron as 35 to 55; and this property is destroyed by an alloy with arsenic, as is the case also with respect to iron and cobalt.

Nickel unites in alloys with gold, copper, tin, and arsenic, which metals it renders brittle. Its alloys with silver and iron are ductile.

Nickel was discovered as a distinct metal by Cronstadt, in 1751; and was obtained from its ore, a native alloy of nickel and arsenic, with very small portions of iron, lead, cobalt, and sulphur, called in Germany *Küpfer-nickel*, or *false copper;* and found in company with silver and copper ores in many countries. Nickel is also found native; but the most curious circumstance regarding this metal is, that it alloys the *meteoric iron*, as will be mentioned in describing that extraordinary phenomenon. *(See Iron.)*

Nickel has been employed to make magnetic needles, as being less liable to rust than steel.

Chapter IX.

Section 1. Iron.

Iron is one of the most generally diffused of all solid minerals; but this metal, though existing in such abundance, is, in its natural state, very unlike what we are hourly accustomed to see it. It presents itself everywhere only as an earthy mass, a dirty impure rust; and even when found in the mine with a metallic lustre, it is still far from possessing those qualities which are necessary to fit it for the endless uses to which it is applied. Man has only to purify gold, silver, &c., but he has, as it were, to create iron; and when we consider that the art of working it, which combines so many proceedings, triumphs over so many obstacles, and which employs fire and iron to subdue iron itself, remounts to the highest antiquity, even beyond the Deluge (Gen. iv. 22), we are almost tempted to regard this admirable art as an inspiration immediately emanating from that Divine Power, which has lavished this metal in such profusion to supply our wants.

Not only does iron, in various states, enter into the composition of most of the compound minerals of which the crust of the globe is composed, but it *forms a constituent* part of many animal and

vegetable substances; it enters into the composition of the blood; and the shades of hue of many a delicate flower are more or less due to its presence.

Iron, when pure, is of a blueish-grey; its specific gravity being 78, it is lighter than most permanent metals, tin and zinc being the only abundant ones which surpass it in this respect.

As regards malleability it ranks after gold, silver, copper, tin, platinum, lead, zinc; iron being the eighth in order, if these metals are arranged according to the degree in which they possess this quality.

In ductility it is only fourth however; gold, silver, and platinum alone surpassing it.

In tenacity it holds the first place. An iron-wire, one-tenth of an inch in diameter, will support a weight of 705 lbs., or six hundred weight and a quarter, while a copper-wire, of the same diameter, will only sustain three hundred weight and a half.

An iron rod, one inch in diameter, as formed at the iron-works, will support seventeen tons and three-quarters without breaking, and an equal rod, as forged into chain-cables, will support nineteen tons, and an inch and a half rod forty-four tons. An inch and a quarter rod, two feet six inches *long, will sometimes* stretch six inches, or twenty *per cent. before it* breaks.

In hardness iron is only surpassed by tungsten, palladium, and manganese; and when in the form of steel, or of *carburet of iron*, it may be made to equal, if not to exceed, these metals.

Iron is only fusible at a temperature of 17977 degrees of Fahrenheit; but, in common with platinum, it possesses the power of being *welded*, or of being made to unite by hammering, when brought to a white heat; this property is of immense importance, and more than balances its difficult fusibility.

Melted iron, if exposed to the air at a still higher temperature, burns with uncommon brilliance, sending out blueish-white sparks, of a dazzling lustre, to a considerable distance. Thin iron-wire is easily burned, either in oxygen gas, or by means of a burning-glass, or by a galvanic battery.

This metal, especially when damped, has a strong affinity for oxygen. The *rust* of iron is an oxide, and is familiar to every one. It unites with oxygen in two proportions, forming the black and red oxides: this last is the most common; it is called *crocus martis*, and is used medicinally; it is also known by the name of *colcothar*, and is used as a polishing-powder, for example, to give the last finish to plate-glass, and on many other occasions.

There are two natural sulphurets of iron; one known as *magnetic pyrites*, the other simple *iron pyrites*, the magnetic power being apparently

destroyed by the excess of sulphur. These will be again mentioned in describing the reduction of the ores, &c.

It is remarkable that pure iron soon loses its magnetic powers; and to render these permanent, it appears that the metal must be combined with either carbon, sulphur, or phosphorus, in a definite proportion.

The carburet of iron, or *steel*, is the most important of its combinations with simple substances. To make good steel the carbon must not exceed one part in sixty; but the carbon in *cast* iron amounts sometimes to as much as one in fifteen.

A small proportion of iron, combined with carbon, constitutes the valuable natural production *plumbago*, vulgarly called black-lead. This ore is found in lumps, in veins, in France, Spain, Germany, &c., but the best and most abundant mine is at Borrowdale, in Cumberland. This is situated at the head of a valley, where the ore fills up the branching veins of a blue rock; the smaller ramifications appear in some places at the surface. There are two workings; one 105 yards deep, and the other thirty yards deep; these are only opened occasionally, as the demand requires, and in the intervals are carefully closed up and secured, a *house being* built over each entrance.

Besides the well-known use of plumbago in the

manufacture of pencils, for which it is better adapted than any other substance yet known, it is employed, like oil, to diminish the friction of machinery, and in the formation of crucibles for chemical purposes.

Iron unites in alloys with most metals, though some of these are obtained with great difficulty; few of them are much employed. The partial one of iron and tin, for tin-plates, will be mentioned under TIN.

The oxide of iron is soluble in many acids, and forms *salts*; but the one principally used in the arts is the sulphate of iron, called *green vitriol*, which is employed in black dyes, and in many other manufactures.

This salt is obtained in large quantities, in several parts of England, by exposing iron pyrites (sulphuret of iron) to the air, on the inclined side of a hill. A strong clayey soil is selected, and gutters are cut in different directions leading to wells, dug five or six feet deep, and two or three in diameter. The pyrites being laid in beds, four or five feet thick, on the spot thus prepared, the sulphate forms on the surface, and the pyrites, washed off by the rain, are carried to the wells. From these the liquid is conveyed, through pipes, to a reservoir, and so to a boiler made of lead, seven feet deep and wide, and fourteen long. In this it is left to evaporate for six or seven days, old refuse iron being added as long as

the liquid will dissolve any: it is then removed to another cistern, and remains for five weeks to crystallize, the remaining liquor being sent back to the boiler. The crystals, when dried, are packed for sale. From five to eight tons of vitriol, according to the strength of the solution, are obtained from one boiler-full.

If the pyrites, when heaped up, is too much moistened, it takes fire, and burns, and spoils the operation, by dissipating the sulphur, which is intended, by its union with the oxygen of the atmosphere, to form the sulphuric acid necessary in the production of the salt.

The sulphate of iron used in medicine is manufactured in London by directly dissolving iron in diluted sulphuric acid. The salt is thus obtained purer and in much shorter time.

Iron oxide, dissolved in acetic acid, or the *acetate of iron*, is used in calico-printing.

Common writing-ink is made by adding a solution of gall-nuts to one of sulphate of iron; this forms a salt composed of iron oxide and gallic acid. To keep this in solution the water of the ink is thickened with gum.

The valuable colour called *Prussian-blue*, is obtained from sulphate of iron and the solution of *oxide of iron* in *hydrocyanic* acid, (formerly called *prussic acid,*) by means of the following process:—

Bullocks' blood, or any other refuse animal matter, as the hoofs, horns, skins, &c., is dried and calcined with potash in crucibles, at a red heat: the hydrocyanic acid, afforded by the animal substance, unites with the potash, and forms *hydrocyanate of potash*.

This salt being dissolved in water, *sulphate of iron*, and *sulphate of alumine* (common alum) in solution, are added to it: the hydrocyanic acid combines with the iron, part of the potash combines with the sulphuric acid, the remainder precipitates the alumine, which combines with the hydrocyanate of iron, and this compound, when washed and dried, is the Prussian-blue.

Iron is found native; but the most remarkable point connected with this ore is, that masses of native iron, alloyed with nickel, and other metals, have fallen, at different times, from the atmosphere on our earth: these masses are called meteoric iron. The records of such events are numerous, from the remotest ages, and independently of the occurrence of the phenomena being absolutely witnessed, masses of iron are found, on the surface, in various parts of the earth, which, from their locality, and from their chemical constitution, differing from that of any terrestrial mineral, could only be derived from such a source.

Thus the traveller, Pallas, found a mass of iron, 1680 lbs. in weight, in Siberia, which tradition

stated to have fallen from heaven: this mass has been examined repeatedly by scientific men, and found unlike any iron of earthly origin.

In the middle of a plain near Durango, in New Biscay, there lies a mass of iron, alloyed with nickel, of such a size, form, and composition, as to leave no doubt that it must have fallen on our earth.

A mass found in the province of Bahia in Brazil, weighs 14,000 lbs.; and another, in the province of Otumba in Peru, weighs fifteen tons.

During one of the expeditions in search of the North-West Passage, made within the last 20 years, the Esquimaux of one district in Greenland were found possessed of knives, made of iron containing nickel, which must have been obtained from meteoric masses.

It is now generally received as the *probable* explanation of the origin of these singular productions, that they are fragments of some planetary body of our system, which has been destroyed, and these portions, as projected into space, have accidentally come within the sphere of the earth's attraction, and consequently fallen to it. Of course, no positive knowledge can ever be gained of their true *origin:* though the *fact* of their falling from the atmosphere is placed beyond a doubt.

Common iron pyrites is an abundant ore of iron, *and is a sulphuret;* it is of a brass-yellow, metallic

in lustre, and in masses, or crystallized in eleven different figures; the primitive being a cube. It is found in every species of rock, in all known parts of the world; although so abundant, it is never worked as iron-ore, but is only employed in the preparation of vitriol, &c.

The ore called *magnetic iron-stone*, contains from 60 to 70 per cent. of metal; it is found abundantly in Sweden, and yields the fine bar-iron of that country, so much employed here for making steel. It is also found in the island of Elba, in Russia, in South America, &c.

Red Ochre is a *species* of red *iron-stone*, it is worked in Bohemia, and yields very good malleable iron. Another species of the same ore is worked for the better iron, from which plate-iron for tinning, and iron-wire is made. Its principal localities in England are Lancashire, and the Forest of Dean, in Gloucestershire. When ground to a fine powder, it is much employed as a polishing material.

Reddle, or *red chalk*, is a species of *argillaceous iron-stone ore:* this is never smelted for iron, but is used to make pencils for drawing. The best comes from Hesse in Germany.

By far the greater part of the iron wrought in England comes from different species of *argillaceous carbonate of iron*; this ore often forming

regular strata, but most commonly occurring in large irregular masses, called *beds*.

From its abundance, it is not excavated by regular mining; but a favourable situation for an iron-work being chosen, a gallery, or *level*, as it is called, is worked in the side of the hill, at such a situation that the mouth may be immediately above the works. The ore, as excavated, is brought along a rail-road, laid down in this gallery, to the opening.

Iron is also obtained largely in France; but Sweden furnishes the best, from the mines of Dannemora. These mines, like those at Fahlun, are immense open excavations; the descent is made in buckets. Mr. Coxe describes the effect of being raised or lowered in these, as rather formidable; but while he was occasionally compelled to shut his eyes, to avoid giddiness, he was passed by three girls ascending in another bucket, who, while standing on its edge, and holding the rope by one hand, were knitting with the other in perfect unconcern: the descent of 500 feet occupied five minutes. Since that gentleman's visit, the depth and extent of the mines has been greatly increased.

The iron mines at Persberg, about two and a half miles from Philipstadt, are perhaps the most interesting and romantic excavations of this kind in the world. The mountain in which they are situated

ENTRANCE TO THE PERSBERG IRON-MINE.

is entirely composed of iron-ore; and they are thirteen in number. Dr. Clarke, who visited these mines, states, "that familiar as he was with mines, his astonishment at beholding these exceeded any thing he had ever before felt on such occasions. For grandeur of effect, filling the mind with wonder, amounting to awe, there is no place where human labour is exhibited under circumstances more tremendously striking.

"As we drew near to the wide and open abyss, a vast and sudden prospect of yawning caverns, and prodigious machinery, prepared us for the descent. We approached the edge of the dreadful gulf, whence the ore is raised, and ventured to look down, standing on the verge of a platform, constructed over it in such a manner as to command a view as far down as the eye could penetrate, for to the sight it appeared bottomless. Immense buckets, suspended by rattling chains, were passing up and down; and we could perceive ladders, scaling all the inward precipices, upon which the work-people, reduced by distance to pigmies in size, were ascending and descending: far below the farthest of these, a deep and gaping gulf opened to the lowermost pits. The clanking of the chains, the groaning of the pumps, the hallooing of the miners, the creaking of the blocks and wheels, the trampling of horses, the beating of

hammers, and the loud and frequent subterranean thunders from the blasting, combine to produce an overpowering effect.

"The ladders for descent, instead of being placed on platforms, as in the Cornish mines, are lashed together, in one unbroken line, for many fathoms, and being warped to suit the inclination of the sides of the precipices, are not always perpendicular, but hang over in some places, so that if the feet were to slip, and the person held fast by his hands, he would hang over the gulf: and these ladders have only wooden-staves, broken and rotten in many places, covered with frozen mud and ice, so that the hands are numbed and rendered unable to grasp firmly.

"As we descended deeper, large masses of ice appeared on the sides of the rock; ice is raised in the buckets with the ore and rubble of the mine. After much fatigue, and no small apprehensions, we reached the bottom, and were hurried along a vaulted level into a prodigious cavern, where, amidst falling waters, tumbling rocks, steam, ice, and gunpowder, fifty miners were in active employment, in a din of noise that rendered all conversation impracticable."

The obtaining the metal, or what may be called *the manufacture* of iron, consists of two great

divisions; the production of *pig-iron* from the ore by smelting, and the conversion of this into malleable iron for use. The following is an outline of the mode practised in Britain.

The ore is reduced in *blast-furnaces;* those in Wales, where the most extensive iron-works are situated, consist of a pyramidal mass of masonry, from thirty to fifty feet square at the base, twenty-five feet square at the upper part, and forty-five feet high; above this is raised a round tower, ten or fifteen feet more. There are two or four doors in this tower, for supplying the material, and an arch on each side at the bottom; one for the workman to get at the furnace, and let out the metal, the others for admitting the blast-pipes. The air is forced through these last, in an equal current, by powerful steam-engines, working a kind of pumps, which propel a volume of air into the furnace, sufficient to maintain the intense heat necessary to smelt the ore.

The *iron-stone,* or ore, in that district, contains, on an average, from 30 to 35 per cent. of metal, combined with carbonic acid, clay, water, silex, sulphur, and perhaps a little arsenic. To purify it as much as possible from these foreign matters before it is smelted, the ore is *roasted,* or calcined, in kilns, which are kept supplied with ore at top, as fast as it is withdrawn from the furnace below;

by this process the ore is reduced 20 to 30 per cent. in weight.

The next important ingredient in the furnace is *coke*, obtained by burning coal in heaps of thirty or forty tons each; the largest pieces of coal are packed loosely, and filled in with smaller at top; this mass is set on fire in several places, and when the air and wind have brought the whole into combustion, the heap is covered over with ashes and dust, to exclude the air; it is left to burn out, and is cooled by throwing water on it, after it has been smouldering for a sufficient time. It is these *coke-hearths*, as they are called, which, on a dark night, are seen illuminating the earth and sky in the neighbourhood of iron-works.

Coke is used as a substitute for charcoal; the latter would be the best material, and is employed in Russia, and those countries where wood is sufficiently abundant *.

* There is a curious fact connected with the iron works of Britain worth mentioning. The reduction of the ore was formerly effected by means of wood, and the consumption was so great that an act was passed in 1581, restraining its use: soon afterwards Lord Dudley discovered that coal was equally efficient, and obtained a monopoly of its employment for the purpose; so highly was this discovery appreciated, that this nobleman's *patent* was expressly excluded from the act of parliament, passed in 1623, abolishing most of those, justly odious, privileges. But though *this invention* has proved invaluable to his country, Lord Dudley *derived little* emolument from it, for his iron-works were destroyed

The third ingredient of the furnace is limestone, necessary as a *flux*, as it is called, that is, to combine with the clay of the ore, and fuse it into a *slag* or cinder; leaving the metal. This limestone is broken into small pieces to fit it for use: if the iron-ore is not *argillaceous*, or clayey, but on the contrary, contains lime, then clay is used as a flux in the furnace.

These three materials are introduced at the door of the cylinder, or *tunnel*, as it is called, at the top of the furnace; as often as is requisite for keeping the furnace full. Each *charge*, or supply, consists of six hundred-weight of coke, with the proper proportion of ore and limestone; but these proportions vary considerably, according to circumstances that need not be explained here.

The iron is *run*, or drawn off, every twelve hours; and five to six tons, or a *sow of pigs*, is obtained in that time. On an average there are fifty *charges* put in during that period, each, perhaps, containing six hundred-weight of ore, or three hundred-weight of roasted ore, in twelve hours. Hence, by calculation, it appears that about three tons of raw ore yield one of pig-iron, and this requires 22½ tons of coke, or 3 tons 15 cwt. per ton of iron, and about

by a deluded mob, and it was not till a century afterwards that his plan was generally adopted, in consequence of the increasing alarm at the enormous consumption of wood at the iron-furnaces.

one ton of limestone for each ton of iron. A furnace, taking into account the fuel necessary at the kilns, and for the engines, supplying it with ore and air, consumes fifty-seven tons of coal, thirty-six tons of ore, and six tons of limestone, every day.

The hole through which the iron is drawn off, is, of course, at the bottom of the furnace, and in front; it is stopt up in the intervals with a mixture of sand and clay. The fluid *cinder*, or scoria, is perpetually running off by another hole, level with the top of the hearth; in order to get rid of the great mass of cinder, the furnaces are built, if possible, on the side of a hill, so that the scoria may flow down the declivity.

The pig-iron thus obtained is of six qualities.

1. Foundry-iron of the first kind, containing more carbon, and this is effected by choosing the best coke, or that nearest to pure carbon, for the furnace. This iron is so soft as to yield to the chisel, and very fluid when melted, and will therefore fill the most delicate moulds. It is, consequently, employed for small, ornamental work, or for that which requires to be accurately of the original pattern.

2. Foundry-iron of the second class, has less carbon, is harder, closer grained, and not so fluid, when melted, as the last; this kind is used for more

heavy works. These two qualities of iron are only used for the foundry.

3. Has less foreign matter still, and is used for either forging or casting; in the latter case, for heavy works requiring great strength and durability, as rail-roads, shafts for machinery, wheel-works, cylinders for steam-engines, &c. It is often called *dark-grey* iron.

4. *Bright iron;* 5. *Mottled iron,* which is only used for forging; and, 6. *White iron,* containing least carbon of all: it is totally unfit for casting, and so thick, when melted, that it will hardly run into the pig-moulds, it is also so brittle that the largest pigs can be broken by a blow with a sledge-hammer, while the chisel makes no impression on it.

Of late years an improvement in the process of reducing the ore has been introduced, by employing, instead of roasted ore, the *scoria,* or *dross,* produced in the different subsequent operations of forging and refining, hereafter described. This is an oxide of iron, containing from sixty to seventy per cent. of metal, but from the trouble and expense of reducing it, it used to be rejected as useless, till the impediments were removed by adding clay in the furnace, to make the scoria approach the composition of natural ore. It is found, however, that this can only be done to a certain

extent, without materially injuring the quality of the resulting metal, and the improvement, though important, is not so successful as it was at first supposed to be.

Pig-iron consists of pure metal, with carbon and oxygen; it is necessary to get rid of a great portion of these two last, to convert pig into malleable iron. This is performed in small furnaces, called *refineries*. These are about three feet square, with a bottom of fire-brick, the back and sides of cast-iron, hollow, to allow a stream of water to run through them, to moderate the intense heat, which would otherwise burn them up in a short time. There are three holes near the top, for the introduction of blast-pipes, and there are iron doors at the back, but the furnace is open in front; the chimney is of brick, run up to eighteen or twenty feet. The hole for drawing off the metal is in front, and communicates, by a short gutter, with an oblong flat mould, twenty feet long, and two broad, placed over a cistern of water to cool the iron.

In this furnace the pig-iron is kept for about two hours melted, exposed to an intense heat, and strong blast, by which a portion of the carbon is got rid of. About sixty to seventy tons of refined iron per week are obtained from each furnace, *and these* are kept going by a double set of men, *working* alternately, night and day.

The next operation is *forging*. Each forge consists of a hammer, two pair of rollers, and a pair, or two, of strong shears, to cut the bars: the *mill* generally contains two pair of rollers, for large-sized bars and bolts, two others smaller, of about ten inches diameter, and two or three pair seven inches diameter, for the smallest sizes of bar; there is also a heavy lathe for turning the rollers. All these are worked by a steam-engine, and as this has to overcome very unequal resistances, at one time only turning the unoccupied machinery, at another forcing iron bars through every pair of rollers, the engine has a powerful fly-wheel of ten or twelve tons' weight, and sixteen feet in diameter, to serve as a reservoir of *power*; this fly-wheel is made to revolve 70 or 80, and sometimes 100, times in a minute.

The first process at the forge-mill is *puddling*, which is melting the refined iron in a reverberatory furnace, for the sake of ridding it still further of carbon; from 3½ to four hundred weight of iron, broken into small pieces, is put at each time into the furnace. When the iron begins to melt, the workman, by means of tools introduced through a small hole in the door, turns the pieces about so as to expose the whole mass as equally as possible to the flame, and when in complete fusion, he stirs it about, changing his tools as they become too hot.

to handle. The fluid at length thickens and forms in masses; these he dexterously moulds into five or six roundish balls, called *puddlers' balls*, or *blooms*: about six to nine *heats* are worked in twelve hours, that is, six to nine charges of refined iron are puddled.

The *blooms*, on being withdrawn from the furnace, are submitted to a few blows from a heavy hammer, weighing four tons, fixed at one end, and lifted by a wheel with cogs, which catch the head in turns, and raising it, the hammer falls down as each cog quits it. This operation, called *shingling*, is for the purpose of making the blooms more solid, and of an oblong shape, better adapted for rolling. The bloom is immediately, while hot, passed through the first set of rollers. The construction of these could only be understood by several figures; suffice it to state, that by passing through the different grooves in these rollers, the iron is reduced to a long thin bar, and from hard, fusible, and brittle, as the metal was before it went to the puddling-furnace, it is, by *puddling*, *shingling*, and *rolling*, made soft, tough, and very infusible.

These bars are cut by the shears to proper lengths, which are *piled* in parcels, and put into another reverberatory furnace called the *balling furnace*. Each pile consists of five or six lengths of *rough bar*, packed very regularly; the heat is suffi-

cient to cause them to run together, and they are taken out at a white heat. These piles are again rolled through series of rollers, till each pile is reduced to the form of bars, each resulting from five or six of the original ones welded together, and thus materially improved in texture and in strength. These bars being cut smooth at the ends into proper lengths, stamped and sorted, are then ready for sale.

In Staffordshire, besides bars, the iron is worked into plates for boilers, sheet-iron of all kinds, nail-rods, rail-roads, &c. &c., at the forge and mill.

The quality of iron bar, of course, greatly varies; that of Wales is the strongest, but the hardest to work, that of Staffordshire being the reverse.

In 1740, 17,000 tons of iron only were made in Great Britain, being the produce of fifty-nine furnaces. In 1788, 68,000 tons were made in eighty-five furnaces; and in 1827, 690,000 tons were produced, being the produce of 284 furnaces; of this quantity 272,000 tons were produced in South Wales, 216,000 in Staffordshire, and 202,000 in other places of England and in Scotland. The value of pig-iron is at present nearly 5*l.* per ton.

An iron work, consisting of five furnaces, a forge, and mill, capable of manufacturing two hundred tons of bar-iron weekly, employs, by calculation, on an average 1108 men, 84 women, and 191 boys.

Steel.

The principal part of the iron which is converte into steel in England, is brought from Sweden Prussia, and Russia, but that from the first countr is most esteemed. The qualities of the metal, a obtained from different mines, is known in ou markets by the peculiar marks stamped by th makers on the bars; one of these marks is th letter L in a circle, and this iron holds the firs rank, being the produce of the celebrated Danne mora mines.

Iron comes over to this country in bars, fro seven to fourteen feet long, and varying accord ingly in breadth and thickness.

The furnace for converting the metal into ste is a conical brick building, in its exterior resemblin a glass-house; within, it consists of two oblon troughs, about fourteen feet long and two to thre deep and wide, made of the best fire-stone; thes troughs are placed so that the flames of a fir kindled beneath may completely surround them This fire is fed through a small door in fron which admits the current of air to raise the hea The bottoms of the *pots*, as they are called, ar *covered* two or three inches deep with pounde *charcoal*, on this the bars of iron are laid, side b *side*, covering the whole surface; then cov

another stratum of charcoal, and then a new layer of bars, and so alternately, till the pot is filled; the whole being covered over with sand or earth that will not easily vitrify. Every other aperture is then carefully closed, and the fire lighted, hard coal being the fuel used: this is kept burning with a considerable degree of intensity for about a week; a bar is occasionally pulled out through a small hole left at the end of the pot, expressly to ascertain whether the process is going on rightly.

At the proper point of carbonization, the furnace is left to cool for six or seven days; and the oven being kept air-tight, the charcoal is not burnt, but is used over again, for making more steel. The bars, after this process, are covered with *blisters*, and in this state the metal is called *blistered steel*, the iron being increased in weight about $\frac{1}{150}$ part.

The next process is to convert the *blistered* into *shear-steel*. This is done by inserting six or eight pieces, thirty inches in length, into a square hoop at the end of a bar of iron, five or six feet long; the bundle is then introduced into a wind-furnace, and heated to a welding heat, sand being repeatedly scattered over it, which, by fusing, glazes over the surface, and protects the metal from being absolutely melted.

When at a white heat the mass is put under a

heavy forge-hammer, and beaten into a rod two inches square; this is cut in two, the pieces are placed together, and the operation repeated; if for best work, the cutting and welding is repeated several times. The steel is now of a fine even texture, and is malleable enough to work into articles.

Cast-steel is made from blistered-steel broken into small pieces, and put into a crucible of clay, holding thirty to forty pounds of metal. This crucible is placed in a draught-furnace, six or eight of which are built in a row, each being a foot or sixteen inches square, and two or three feet deep, the mouth being level with the floor: the air is supplied from a lower chamber. The crucible is stopt up air-tight with clay, and imbedded in coal, the mouth of the furnace being covered close down with bricks in an iron frame.

In about four hours the mass is melted, and the cover being removed, a man, defended by sacking over his arms, body, and legs, thoroughly wet through to protect him from the intense heat, withdraws the crucible, and pours its contents into moulds, so as to form either bars two inches square, for *tilting*, or plates, six inches broad, twelve or eighteen long, and one thick, for *rolling*.

The manufacture of articles of steel affords a *most striking* example of the value conferred by *human labour*, and its divisions, on the raw pro-

duce of nature. A pound of crude iron costs twopence; it is converted into steel (in wholesale); that steel is made into the balance-springs for watches, each of which sells for twopence, and weighs $\frac{1}{1000}$ of a grain. Allowing for waste, a pound of iron will make 50,000 springs, and the twopenny-worth of iron becomes worth 416*l.* 13*s.*, or increased in value 50,000 times by labour only, for there is no other material added but the carbon to form the steel, the value of which for 1 lb. of iron, is too small to be appreciable*.

Section 2. Molybdenum.

This metal was discovered by a continental chemist of the name of Hjelm, in 1782, in a sulphuret named Molybdena, which has been long known as occurring in company with tin, copper, and other ores. Its specific gravity is 86; it is so infusible that no chemist has, as yet, succeeded in obtaining it in a pure metallic form. It unites with oxygen in two proportions, and forms two acids: but comparatively little is known of it, and no use has been made of it.

* *Economy of Manufactures*, by Mr. Babbage.

Section 3. TIN.

TIN is of a brilliant white colour, with a specific gravity of 73, it being rather more than seven times heavier than water. In hardness it surpasses lead, but is inferior to gold: it is very malleable, and may be beaten out into leaves only $\frac{1}{1000}$ of an inch thick, termed *tin-foil;* but it might be reduced to half that thickness if required. In ductility it is only superior to lead. A wire $\frac{1}{10}$ of an inch in diameter will support a weight of 47 lbs.

Tin is very elastic, and a singular crackling noise is heard when it is being bent; this property is common to cadmium as well as tin.

Tin melts at a temperature of 442 of Fahrenheit, but it requires a high heat to volatilize it. It is but little acted on by air, or water, at ordinary temperatures; steam, however, passed over red-hot tin, oxidizes the metal rapidly, the hydrogen of the water being liberated.

Tin-putty, as it is called, is an oxide, used for giving the last polish to steel, glass, &c. &c.

Tin unites with many metals, and forms valuable alloys. Some of these have been mentioned under the various metals which unite with it. They will, *however,* be recapitulated here with their different *proportions.*

Ten to twelve parts of tin, with 90 or 88 parts of copper, forms the bronze of the ancients, used for weapons, knives, &c., and in modern times for cannon.

The same metals, combined in the proportions of one-fifth of tin to four-fifths by weight of copper; or of one-third of the former to two-thirds of the latter, forms one species of *Bell-metal.* Brass, spelter, and even lead, or silver, are sometimes added in various proportions, according to the fancy of the founder.

The alloy of which the Chinese make their *gongs,* is composed of 80 parts of copper to 20 of tin.

One part of tin, with two of copper, or, according to Mr. Edwards, 32 of copper, 15 to 16 of tin, with one part of brass, one of arsenic, and one of silver, forms the best *speculum-metal* for reflecting telescopes.

Tin and lead, in very various proportions, constitute a species of *Pewter,* and in equal weights form *plumbers' solder.* The best kind of pewter for engraving music on, is made of tin and antimony; and the alloy, commonly called pewter, of which the quart and pint measures used for holding beer in London are made, is a compound of twenty parts of tin with one of copper; and according to the purpose for which it is intended, or according

to the particular theory of the manufacturer, lead, zinc, bismuth, or antimony, are added.

Vessels for culinary purposes, made of copper or brass, are *coated* on their inner surface with tin, in order to prevent the liquids put in them being rendered poisonous, by dissolving some portion of the former metals; which most liquids, occurring in articles of food, would do in some small proportion. This *coating* is effected in the following manner: the surface, to be covered, being first scraped, or scoured, perfectly clean and bright, sal-ammoniac is strewed over it, and the article is made hot enough to melt tin if applied to it; this metal, or an alloy of equal parts of tin and lead, is then rubbed over the parts to be coated.

Copper and brass are also tinned by a process called *wet-tinning*, used in the manufacture of pins. A solution of one part of *cream of tartar*, two of *alum*, and as much of common salt, is made in water, tin in grains or filings is added, and the whole boiled; the pins, first cleaned by *pickling* in week acid, are put into the solution, and after remaining some time, become coated with an uniform surface of tin.

Iron tacks, or other small articles, are also tinned, by being put into a stone-ware bottle with *sal ammoniac* and grain tin; the bottle is then *put on a charcoal* fire, and frequently turned, so as

to expose all the tacks equally to the action of the mixture. When the tinning is completed they are washed in water, and dried in bran or saw-dust made hot.

But the most important application of tin to the covering of the surface of other metals is employed in the manufacture of *tin-plates;* of which saucepans, and numberless articles of household furniture, are so neatly and so cheaply made. The process is interesting enough on all accounts to merit description in detail*.

The *latten*, or plates to be *tinned*, are made from the best Welsh iron, or iron of the finest quality, which has been reduced from the ore by means of charcoal instead of coke. This is rolled out into plates three-eighths of an inch thick; these plates are then cut in pieces, ten inches long by six wide, which are repeatedly heated and rolled until reduced as thin as the operation will admit of. Each sheet thus formed, is then doubled and rolled again, then doubled again, and the rolling repeated; the jagged edges are cut off by stout shears, and the quadrupled plate reduced to a certain size. It is then cut across, and the eight pieces being ripped asunder, are piled in heaps, 225 plates constituting what is called a *box*.

* The account is abridged from Lardner's *Cyclopædia*, vol. 3, on Manufacturers in Metal.

Another workman then bends each plate across the middle, so that it resembles in its profile the letter U. The plates are next steeped in diluted muriatic acid for four or five minutes, and when dried again, are placed in a reverberatory furnace, where the heat causes a thick *scale* to come off, the form of the bent plate, set on its doubled edge, allowing the heat to get equally at both sides, which it would not do if the plates had been laid flat in the furnace. When cold, they are beat flat again on a cast-iron block, and then rolled between hard, polished, steel rollers, screwed so tight that the utmost pressure is exerted on the plates; by this operation they are made perfectly flat, smooth, and elastic.

The plates are next placed in troughs containing water, in which bran has been steeped for nine or ten days, so as to acquire a sufficient acidity; and in this *lye* they remain for ten or twelve hours.

The next operation, termed *pickling*, consists in immersing the plates for about an hour in diluted sulphuric acid, contained in a leaden trough, divided by partitions, each division holding a box of plates, a flue passing under the trough, by heating the liquid, hastens the action of the acid, which makes the plates perfectly bright. They *are then* dipped in clean water, and scoured in it *with sand* and *hards*, to clean them still more com-

pletely from any remaining rust or oxide, for the smallest spot of this would spoil the subsequent operation, by not allowing the union of the tin and iron in that place. The plates thus prepared are left, until wanted, in fresh pure water, to keep them from rusting again.

A strong vessel of cast-iron, capable of holding two to three hundred of these sheets of iron, and about five hundred-weight of tin, is fixed, so as to be heated by a fire from beneath, and by flues which go round it. This *bath* is nearly filled with a mixture in equal proportions of *block* and *grain* tin, and a quantity of tallow, sufficient to cover the metal when melted to the depth of four inches. The use of this grease is to preserve the molten tin from oxidizing by the action of the air, and it is found that it also assists the union of the two metals.

Previous to tinning, the plates are immersed for about an hour in another vessel, filled with melting grease only, and they are then dipped into the bath of tin edgewise; two to three hundred being put in, they usually remain an hour and a half in the metal, which is kept as hot as is consistent with not setting fire to the grease. The plates are then taken out by tongs, and placed on an iron rack, or grating, for the superfluous tin to drain from them. But even after this process there is

twice or thrice as much left on the iron as is necessary, and to remove this is the object of the next operation, called *washing*.

Four more iron troughs of the same lengths and depths as the first, but of different widths, are, like that, set over flues, on a brick foundation, so as to be at a convenient height for the workman.

The first pot is filled with the best *grain* tin only, melted; the next with clean tallow, the third has only an iron grating at the bottom to receive the plates, and the last has a small quantity of melted tin in it, sufficient to cover the bottom to the depth of a quarter of an inch.

The workman puts the plates which have been tinned into the *wash-pot*, the heat of the melted tin in which soon melts all the loose metal on the surface: he then takes out the plates singly, and holding them in a pair of tongs by one hand, brushes the two sides with a hemp brush of a particular kind, to remove the superfluous metal; he then dips the plate again in the tin, and withdrawing it instantly, plunges it in the trough with the grease in it, in which it only remains just long enough to remove the extra tin; the second dipping in the metal after brushing being intended to remove the marks of the brush, and to equalize the coating; but as this dipping causes too great a quantity of metal to adhere to the surface, the

grease is intended again to separate this extra quantity. The plates are then left in the trough with the grated bottom to cool, this vessel having no flue under it; but as they stand upright in the trough, the tin before it hardens subsides a little to the bottom edge, and forms a rim, or *list*, along it. The metal collected in this greater thickness must be saved; and this is done by an assistant who dips that edge into the shallow fluid tin, in the last, or *listing-pot*, and the heat, remelting the edge of subsided metal, this runs off on a smart blow being given as the plate is withdrawn.

The plates are finally cleansed from the grease by being rubbed with *hards*, in bins of dry bran, by women, and are packed in boxes for sale. Such is the perfection to which the manufacture is carried, both in the economy and quickness of each of these numerous processes, that of nineteen sorts into which the plates are classed, according to their size and quality, the dearest is sold at the wholesale price of 4·68 pence, or a little more than fourpence halfpenny for a plate measuring 15 by 11 inches; and of 1·50, or three-halfpence, for one measuring $12\frac{3}{4}$ by $9\frac{1}{2}$ inches: the first of these qualities being at the rate of 3·71 pence per lb., and the last at the rate of 3·36 pence per lb.

As an instance of the dexterity acquired by the division of labour an expert washman will wash,

that is, dip twice in the tin, and brush on both sides, and plunge in the grease, 5625 plates in twelve hours!

It is not generally known that in England but little tin is used in manufacturing articles of the solid metal, the consumption of the pure metal being chiefly in the state of *leaves*, or tin-foil: the great quantity of metal annually obtained from the mines, is either employed to form the various alloys before enumerated, or else to export to other countries.

What are called *block-tin* goods, are made of tinned iron, only of a thicker substance and better quality, and these being hammered on anvils with polished steel hammers, acquire that even, silvery look, instead of appearing wavy and glistening, as the ordinary unplanished wares do.

Solutions of tin in nitric, muriatic, and tartaric acids are much used as *mordants* in dyeing.

Next to tinned iron-plates, the most important alloy of tin, which has nearly superseded the use of pewter in domestic utensils, is that called *Britannia metal:* this is a mixture of $3\frac{1}{2}$ cwt. of the best block tin, 28 lbs. of regulus of antimony, 8 lbs. of copper, and 8 lbs. of brass. The tin is first melted and raised to a dull red heat, the other *ingredients* are added in order, in a melted state; *the mass being* well stirred after each addition, to

effect a thorough union. The alloy is cast in slabs, or ingots of various sizes, for convenient use; it is then flattened into sheets, by rolling between steel rollers.

Tin appears to have been one of the earliest discovered metals, and is mentioned repeatedly in the mosaic writings. That the Phœnicians came to Britain for tin is generally believed, and it is certain that the metal was obtained from Cornwall before the time of Herodotus. This county being, generally speaking, *richer* in the ore than any other known part of the world, though the metal obtained from Malacca, especially from the small island of Banca, is superior in purity to English tin. Tin is also found at other places in the East, as well as in America, Spain, France, Saxony, &c.

Its ores generally occur in rocks of granite, gneiss, &c., in veins or fissures, called *lodes*, in Cornwall; or in horozontal beds, called *floors*, or else scattered loosely among gravel and sand, which has been washed down from the hills by mountain-streams, as gold is found in tropical countries.

The principal mines in Cornwall are in the neighbourhood of St. Austle, and the mode practised there of reducing the ore is briefly as follows. The ore is pounded, or *stamped*, on the spot, in the stamping-mill, which consists of heavy beams of

wood, shod with masses of iron, weighing $1\frac{1}{2}$ cwt.; these beams are raised by means of water-wheels, and fall by their weight on the ore, which is placed in troughs, through which a small stream of water runs, in order to wash away the ore as it is pounded fine; one end of the trough is formed of iron plates pierced with holes, through which the ore is sifted, as it were, and passes into other troughs, or pits, in which it settles from the water in different degrees of fineness.

The ore, thus pounded, is washed in vats called *keeves*, to free it from all soluble earthy matter and dirt, previous to its being smelted; when thus purified, the mass consists of tin alloyed with arsenic, iron, sulphur, and other minerals. When the first-named metal exists in the ore, it is necessary to calcine it at a low red heat, in large reverberatory furnaces, for several hours, to dissipate that substance as well as the sulphur. This process is so noxious to the men engaged in it, that they die at an early age, after being employed for but a few years.

The ore is next mixed with about one-eighth of its weight of small coal, or *culm*, and about 600 cwt. of the mixture is put into each reverberatory furnace, which quantity, in about six hours, yields *350 cwt.* of tin; the fluid metal being drawn off *into moulds*, thus forming blocks, called *pigs*, *weighing* from $2\frac{3}{4}$ to $3\frac{3}{4}$ cwt. each.

In some works the pigs of tin are again remelted in a furnace, at a low heat, and the first portion that fuses, being the purest, is drawn off, and constitutes what is called *grain-tin*. The heat is then raised till the rest of the mass melts, which it does more slowly than before, owing to the copper, iron, &c., by which it is still alloyed. This second batch is again cast into *pigs*, and forms the ordinary tin.

All tin is stamped, and pays a duty to the Prince of Wales, as Duke of Cornwall, or to the sovereign.

The tin which is obtained from the ore washed down by streams, is much purer and more free from arsenic than that from the lodes.

The largest *stream-tin* work is at Carn, near Redruth, situated in a valley, through which a river once flowed, but its course has been turned, for the sake of getting at its *bed*, which contains the ore. The upper part consists of a stratum of clay, shells, earth, &c., about fifty feet in thickness, containing hazel-nuts, the antlers of deer, and other diluvial deposits; beneath is the ore, in lumps and grains of various sizes, which have thus subsided by their weight, and form a bed of from one to five feet in thickness.

The whole of the upper stratum being cut away as the mining operations proceed, the works resemble a vast gravel-pit, of more than a mile in length, and two or three hundred feet broad, kept clear of

water by powerful pumps. The ore is carried in barrows to the head of the works, and thrown under a fall of water, to wash away the earthy matter; the clean ore is then sent to St. Austle, where it is pounded and sifted, and reduced in common blast-furnaces. The ore is so rich as to yield from sixty to seventy-five per cent. of metal.

Some of the Cornish mines have been carried to a considerable distance under the sea. That of Huel-Cok, which has been abandoned for many years, on account of the increasing danger from this source, was carried far beyond the low-water mark; in many places there was only from one to three fathoms thickness of rock over head, between the mine and the ocean; and the noise of the waves, during storms, when stones and rocks were rolled along the bed of the sea, was heard in the mine, in the most appalling manner. The miners have frequently fled from their work, in fear of the water breaking through upon them.

About a century ago, some tin-veins were observed in a bed of gravel which was left dry at low water, in the middle of the harbour of Penzance, at about two hundred yards from the shore. After several unsuccessful attempts to work this spot, a poor miner, without money to purchase assistance, *undertook*, alone, to make a new effort; he em*ployed three* summers in sinking a pit, being only

able to work about two hours at it each day, on account of the tide, and always finding the opening filled with water at his return, which he had to empty out before he could proceed. When he had got to a certain depth, he, with great labour and ingenuity, built a turret of wood round the pit, capable of keeping out the sea. At length, after many disappointments and failures, he reaped the reward of his toil, for he established a regular mine, from which, in about six months, he obtained tin to the value of 600*l.* This singular man died in 1791, at the age of 70; his mine of Huel-ferry, as it was named, having, during preceding summer yielded ore worth 3000*l.* The work has since been abandoned, a vessel, having struck against the tower, during a storm, and destroyed it.

There are, in Cornwall, 45 copper-mines, 28 tin-mines, 18 of copper and tin, 2 of lead, and 6 of Cobalt, Antimony, and other minerals; so various are the products of the county, that except Platinum, Mercury, and four or five others, *all* the known metals are found in it, in different degrees of abundance.

About 27,264 *blocks* of tin, each weighing from $2\frac{3}{4}$ to $3\frac{3}{4}$ cwts., are, on an average, annually produced in the county.

An idea of the extent and importance of the

mining-operations there may be formed, when it is estimated that 40,000*l.* worth of gunpowder alone, for blasting, is annually consumed by the Cornish miners; and the population engaged directly in the operations amounts to 60,000 persons.

Section 4. Antimony.

This metal is of a blueish-white, and considerable brilliance, with a specific gravity of 67; it fuses at a temperature of 932, but requires a greatly increased heat to volatilize it.

It is not malleable, being so brittle as to be easily reduced to powder by trituration, or pounding, and its ductility is inconsiderable; a wire one-tenth of an inch, has been formed of it, which only supported ten pounds. When rubbed it has a peculiar taste and smell.

The metal exposed to air or water, undergoes no alteration, but at a red heat it decomposes steam so rapidly, as to produce a violent explosion, the oxygen of the water forming an oxide with the metal, and the liberated hydrogen burning.

There are three oxides, two of them being acids; the other is employed in colouring glass purple, and *in vitrifying* the earths.

Antimony combines with chlorine so rapidly as

to produce a shower of fire, if it be poured, finely powdered, into a glass jar, filled with that gas.

It unites with many metals, some of the alloys being useful. That with lead is used for the plates on which music is engraved. With tin it forms a kind of pewter, and with lead and copper it forms printers' type metal.

An oxide combined with one of lead forms Naples yellow, and is used in enamelling.

Emetic tartar, is a salt composed of potash and tartrate of antimony.

Hydrochloric acid forms a salt with the oxide, called *butter of antimony*, which is highly corrosive.

Antimonial wine is *tartrate of antimony* dissolved in alcohol.

In the East, preparations of antimony are employed by the women to stain the eyelids; the Arabic name of one of these is *kohol*, which, with the article *al*, is the origin of the name now given to spirit of wine. Its use as an ornamental pigment for rendering the eyes brilliant, is of the highest antiquity, the custom is alluded to in Scripture, (Jer. iv. 30, and Ezek. xxiii. 40.)

Antimony occurs native; in ores, as sulphurets called grey and red antimony; and as an oxide.

It was not known to the ancients as a metal, but they were acquainted with its oxide, which

Pliny calls *stibium*, as accompanying silver. Basil Valentine, a monk of Erfurt, appears to have been the discoverer of the metal, in 1620; it is stated that he practised as a physician, and made trial of the new substance on some hogs of his convent, it acted as a cathartic, and the pigs fattened; being induced, from this success, to administer it to his brother monks, he gave too strong a dose, and they died under its effects: hence, as alleged, its name of Antimony.

Section 5. Zinc.

This metal is also blueish-white, with a fine granular fracture; its specific gravity is 7·7. It is more malleable than iron, though less so than lead, and more ductile than tin or lead, but not very elastic. A wire one-tenth of an inch in diameter will support a weight of 26 lbs. If heated to a temperature of 250 degrees, its malleability is greatly increased, and it may be rolled out into thin sheets, between steel rollers. But if the heat greatly exceeds this, or mounts to 400 degrees, it becomes quite brittle, and may be pounded to powder. Zinc fuses at 500 degrees.

Zinc tarnishes by exposure to air, but does not *oxidize* much in such circumstances; and it decomposes water but slowly at common temperatures;

steam, passed over red-hot zinc, is, however, rapidly decomposed, and an oxide of the metal formed. The *flowers of zinc*, and the *philosophers' wool*, of early writers, is the pure white oxide of this metal.

Zinc alloys with iron, copper, antimony, gold, silver, lead, tin, mercury, potassium, and sodium: the most important alloy, namely *brass*, is that produced by copper and zinc, in variable proportions, of 68 to 65 of copper, with 32 to 35 of zinc: but the proportions of the more valuable kind, called *Dutch brass*, is 70 to 30, the metals being more free from lead than the common sort. (For the mode of making brass, see COPPER.)

It is reported by some, that the *Tutenag* of the Chinese is pure Zinc, while others believe it to be an alloy of two or three metals, zinc being one; little, however, is known about it.

Zinc was not obtained in the metallic form till the sixteenth century, though its ores were known to the ancients, and used by them in the formation of their brass or bronze.

It does not occur in a native state; its most abundant ore is the sulphuret, called *Blende*, common in most veins, which contain sulphurets of iron, lead, copper, &c., in every country.

The ore is roasted, pounded, mixed with charcoal, and reduced in earthen melting-pots,

and the metal either passes melting through iron tubes, or is volatilized, according to the heat applied; and is collected in vessels of water in either case.

The ore called *Calamine* is a *carbonate of zinc*; that from Freyberg also contains Cadmium.

Zinc is now much employed in making rain-water-pipes, gutters, chimney-pots, &c., which are formed of thin zinc plates.

The principal supply in this country is furnished by two works in the neighbourhood of Bristol, and by another near Swansea.

Zinc is of essential importance to scientific men, in forming galvanic and voltaic batteries, these being composed of alternate plates of copper and zinc.

The salt *sulphate of zinc*, called *white vitriol*, is used in medicine as a violent emetic.

Chapter X.

Section 1. Tellurium.

This metal was obtained in 1782, from an ore of gold, with which metal it is found combined in the Transylvanian mines. In colour, it is between tin-white and lead-grey; it is very light, with a specific gravity of 61: easily fused, and very volatile. It has not been used in any form, and is only interesting to scientific chemists and naturalists.

Section 2. Manganese.

This metal is little known in its pure state, to which it is with difficulty reduced, owing to its strong affinity for oxygen. Its most abundant ore is the black oxide, a soft and brittle green-black earthy substance, abundant in Devonshire, and other parts of England, which was long considered as an iron ore.

The metal is obtainable in small quantities from this ore, by heating it in an intense furnace, with charcoal and a little oil; it is grey, finely granular, and softer than cast-iron; its specific gravity is

only 58. It fuses at a temperature above that necessary to smelt iron: when exposed to the air, it gradually oxidizes, and crumbles into a black powder.

The common oxide is a valuable substance to chemists, as that from which pure oxygen gas is most easily obtained. It is also used by glass-makers, to remove from the glass the green colour which the iron, contained in the sand or in the flux, is liable to give it. The oxide is likewise employed, largely, in the manufacture of chloride of lime, for the use of linen-bleachers.

Section 3. TITANIUM.

THIS metal is of a golden colour, with much lustre; brittle, elastic, fusible only at an intense heat.

It was discovered in the year 1791, in a black sand in Cornwall, and the mineral called *red schorl* was afterwards ascertained by Klaproth to be nearly a pure oxide of Titanium: it has since been found in a few other minerals, as Iserine, &c., (see page 44.) The beautiful filaments, often seen in rock-crystal, consist of this metal.

It has been employed, on some occasions, to produce a brown or yellow, in porcelain-painting.

Section 4. Chromium.

The name of this metal is derived from the Greek word for *colour*, on account of the varied and beautiful tint of its ores and salts.

It is white, brittle, capable of a high polish, but very infusible.

Its principal ore is found in Siberia, and is a salt of lead, formed by an acid oxide of Chromium; the ore is of a splended red. Another ore is a similar salt of iron, but more abundant, which is found in France, Styria, and several places in North America, as well as in Siberia.

The ruby and the emerald owe their different hues to this metal.

In the fine arts, the richest yellow colour ever discovered is obtained from preparations of chromium. It is also used in tinting glass of an emerald green.

Section 5. Columbium

Was discovered in 1801, in a mineral brought from North America, and hence received its name. Little is known about it, except that it is of a dark-grey colour, very dense, and difficult of fusion.

Section 6. Rhodium

Was discovered by the late Dr. Wollaston, together with Palladium, in crude Platinum: its extreme hardness would cause it to be eminently useful, if it were more abundant. The knibs of artificial pens are made of it, as a substitute for ruby. The name is taken from the Greek word for a *rose*, some of the preparations of the metal being of that tint.

Section 7. Iridium and Osmium

Were detected by the late Professor Tennant, also in crude Platinum; they are excessively infusible, the first especially. Little is known about them as metals, and they have not been applied to any use. The name Iridium is derived from Iris, some of the salts of that metal having varied tints like a rainbow; Osmium was so called from the strong odour of some of its compounds, the name being derived from the Greek word for smell.

Section 8. Cerium

Was discovered in 1750, in a mineral resembling *Tungsten*, brought from Sweden.

Chapter XI.

We now come to a class of metals, differing in many respects from all that have preceded: the most remarkable circumstance attending them has been already (see p. 7) alluded to, namely, their high affinity for oxygen, which prevents their being ever found, or remaining long in the metallic form. Little or nothing consequently is known about their properties as *metals*, while, as *oxides*, several of them, combined with other substances, form some of the most important and generally-diffused materials of the globe.

Section 1. Aluminum.

The earth *alumina* is an oxide of this metal. When alumina is obtained pure by chemical processes, for it is never found so in nature, it is white, destitute of taste and smell, with a specific gravity of 2.

The metal itself has not yet been obtained in a separate state, but the analyses to which alumina has been subjected have clearly shown that it is a metallic oxide. It was from the action of a galvanic battery on alumina, that the late Sir Humphry Davy arrived at this conclusion.

Alumina is an ingredient in all clays, or *argillaceous* earths, but rarely constituting more than a

third or fourth part of them: the peculiar smell which invariably attends its presence, is attributed to the presence of some oxide of iron. Alumina is, next to silicon, the most abundant of all earths, it enters into the compositions of many of the rocks and strata forming the largest mountain-chains, and few soils are free from it.

Sapphire.—This precious stone, which next to the diamond is the hardest substance in nature, consists of nearly pure alumina, the best specimens not containing more than 1 or 2 per cent. of other ingredients; these are usually either oxide of iron, which imparts to the sapphire its beautiful hues, or silex, or lime. The sapphire crystallizes in six-sided prisms.

There are several varieties of this gem, and of different colours; the *white*, the *blue*, or *oriental sapphire*, which is the most esteemed, the *oriental amethyst*, the *oriental topaz*, and the *oriental emerald*, which three last must not be confounded with the other precious stones of the same names.

The sapphire is found in sands, and alluvial matter in several countries; the finest come from the kingdom of Pegu, from Ceylon, &c. It has been lately employed in the formation of small lenses for microscopes, for which purpose its *optical* properties peculiarly adapt it.

The Oriental Ruby is a variety of the same mine-

ral genus as the foregoing, differing from it in containing rather more silex, and in not being quite so hard: it occurs in similar localities in the East. These two precious stones rank in value and estimation next to the diamond, the Ruby deservedly taking the second place, from its splendid colour. When the specimen is fine and free from flaws, a ruby of large size will fetch from 10,000*l.* to 15,000*l.* The finest in Europe is in the collection of the late Mr. Hope.

Corundum, is only the sapphire and ruby in a less pure state, containing more silex and oxide of iron than those precious stones: it is of a crystalline, granular texture, and is found imbedded in granite or limestone rocks in many parts of the East: it varies in tint, from being sometimes nearly colourless and semi-transparent, to green, brown, red, &c., and occasionally to black and opaque. It is employed to cut and polish gems in the East, and occasionally also in Europe, but diamond-powder though it is far more expensive, is preferred here, from its more rapid action.

Emery is a variety of corundum, found in the East and in various parts of Europe, either in blackish or dark-grey masses, or else as a reddish brown sand; the principal supply of this truly valuable mineral is derived from the island of Naxos, but it is also found in many other parts of Europe.

The masses are ground fine in steel mills, and sorted into various degrees of fineness by the following simple and ingenious contrivance. The powder is well mixed up in vessels filled with water, and left to stand; the coarser particles, from their weight, soon settle to the bottom, and the liquid, containing all the finer emery still floating in it, is drawn off into another vessel, in which it is left till a new sediment of the grains of the next degree of fineness takes place. The process of drawing off is thus repeated as often as necessary, a new portion of emery being obtained each time, increasing in fineness; the last takes half an hour or more to subside from the infusion.

Emery-paper is made by sifting the mineral over coarse paper, moistened on one side with size, which causes the powder to adhere when the paper dries. The use of emery, both in powder and as emery-paper, in polishing steel and other metals, glass, marble, &c. &c., is well known.

The *Turquoise* consists of alumina, with varying proportions of oxides of copper and iron, and with water. It is opaque, of a bright greenish blue colour, and is found in roundish masses, from the size of a pea to that of an egg: the best specimens come from Persia. It is an ornamental stone, but *not now* in great estimation, except when set in *company* with diamonds or pearls, the effect of

which is much enhanced by the contrast of colours.

Topaz.—This stone varies more than most gems, both in size, form, and colour: the Brazilian species is often as transparent as a piece of clear ice, when the surface is melting, and resembles that substance in its limpid appearance; in other countries it is green, blue, yellow, or red of various shades. When not crystallized, it is found in rounded masses, sometimes weighing several ounces.

Topaz is rather harder than quartz, and consists of 50 per cent. of alumina, 30 of silex, and 20 of fluoric acid, when transparent; but the coloured varieties contain oxide of iron and other matters. Topaz is found in granite and other primitive rocks in every part of the world, chiefly in veins of tin. The Scotch pebble, called from the place where it is found, Cairn-gorum, is a topaz.

Spinelle ruby differs from the Oriental ruby, not only in colour, &c., but in the more essential particular of its crystal, which is an octohedron. A very remarkable deviation from the regular laws of crystallization is of frequent occurrence with this stone, though by no means confined to it: the crystals presenting this peculiarity are called *macles;* they often appear as if a regular crystal

had been cut in two, and the parts turned half-round, and put together again. When perfect in form and colour, the spinelle ruby is a valuable gem, but inferior crystals are common.

The *Balais ruby* is a variety of the spinelle; like most other gems, these are found in the sands of streams, having been washed down from their original situation, which is not accurately known.

Alum. This familiar substance was long ago known to be a salt, produced by the combination of sulphuric acid with some earth, and a small quantity of potash, and oxide of iron; but it was not till 1754, that this earth was shown to be a distinct, and hitherto unknown one, to which the name *Alumina* was given, from that of the original body. Alum is found naturally in several forms, on argillaceous rocks and strata: it is easily sublimed by heat, and is, consequently, found in volcanic districts, as in the Solfatara. Alum has a strong astringent taste, and antiseptic properties, which render it valuable in dyeing, paper-making, currying, and many other arts. If wood be saturated with a solution of alum, it is rendered nearly fireproof. Tallow-chandlers add alum to their grease, to make it harder, and bakers put some into their dough, to make the bread light and white: London *bread is,* on this account, considered as unwholesome compared to that which is not so adulterated.

Alum is used as a styptic in medicine: one of its singular applications is in the formation of Homberg's pyrophorus. Melt three parts of alum, and one of flour, or sugar, together in an iron ladle, dry the mixture till it turns black; pound it fine, and put it into a retort, and subject it to a low red heat, till a blue flame issues from the orifice. When this has burnt for fifteen minutes, stop the mouth of the vessel air-tight, till the whole has cooled, and cork it well in glass bottles, exposing it to the air in the process as little as possible. This substance will ignite spontaneously in the open air.

There is a manufacture of alum at Tolfa, near Rome. The natural mineral, which is very impure, is broken and calcined; it is then exposed to the air, and frequently watered, which, in about two months, reduces it to a paste; it is next washed, and the alum crystallizes as the water evaporates. This process of solution and evaporation is repeated, for the purpose of purifying the salt still further, and potash and ammonia are added to the solution. This is the *Roman alum* of commerce; it is a triple compound, of sulphuric acid, alumina, and potash, and it is better than the Roch-alum, so named, from its being made near Roccha or Edessa, in the Levant.

Near Whitby, in Yorkshire, there has existed a manufactory of alum since the reign of Elizabeth;

but our home-made alum is the worst of all. Alum is made in great quantities in China; and 785 tons of it were exported from Canton alone, in 1831.

Section 2. Thorinum and Yttrium.

These metals are the bases of two earths, *Thorina* and *Yttria*, recently discovered in some rare minerals; but very little is known about them. Like the preceding metal, aluminum, they have not been obtained in a separate state, but experiments with the earths have indicated in the most decided manner that they are metallic bodies.

Section 3. Zirconium.

The earth Zirconia, like most others, when pure, is white and tasteless, and was found, by the agency of galvanism, to be a metallic oxide, in a manner analogous to that by which the other earths and alkalies were proved to be similar compounds. The metal has not been, as yet, examined in its pure state.

The *Hyacinth* is the best known of the three minerals of which zircon is the principal ingredient; all are crystallized bodies, and are found in beds of streams and rivers in the East, and in other places, along with rubies, sapphires, &c. The hyacinth is only curious in collections, it is little, if at all, used as a gem.

Section 4. Glycinum.

The *Emerald* and *Beryl* are crystallized compounds of an earth named Glycina, with silex, alumine, lime, and oxide of iron; the splendid green of the first is attributed to the presence of oxide of chromium.

The finest emeralds come from Peru; the principal mine is in the valley of Tunca in Santa Fé, where they are found in veins, in granite. It is a justly esteemed jewel, harder than quartz, but surpassed in this respect by the beryl. The aqua-marine is only a variety of this last stone, of a more transparent texture. All three are found in many parts of the world.

The metal which is the base of the earth glycina, was shown to be one by Sir Humphry Davy, from the effects produced by galvanic action on the earth, but glycinum has not yet been obtained in a separate state.

Chapter XI.

The metals which remain to be described, are the bases of a class of substances termed *alkalies*, or *alkaline earths;* the chemical characteristics of which are, that they turn vegetable blues green, and that they neutralize acids, combining with them to form particular salts. These two general characters are all that can be properly alleged as essential to the alkaline principle, for, like acids, the various substances themselves differ greatly in their apparent and sensible properties.

Section 1. Calcium.

This metal was obtained by Sir Humphry Davy, by means of galvanic agency, from *lime;* and being received, during the process, into a vessel filled with naphtha, it was excluded from oxygen, and, consequently, retained its metallic appearance, which resembled that of silver. But no further investigations can be made regarding its properties as a metal, for the instant atmospheric air is admitted to it, it absorbs oxygen rapidly, burns with an intense white light, and reproduces *lime, which is* an oxide of calcium.

Lime does not exist in a pure state in nature, it *has so strong* an affinity for carbonic acid, as to

absorb it from the atmosphere, and is thereby converted into *carbonate of lime*, one of the most abundant substances in the mineral kingdom, constituting, in various forms and combinations, extensive strata, and the largest mountain-chains. By also contributing especially to the fertility of the soil, it is doubly important to man, from its beneficial effects on vegetation; carbonate of lime being one of the most powerful manures employed in agriculture.

Lime is a white earth, fusible only by the heat of a galvanic battery, or of a gas blow-pipe; it is extremely caustic, and if water be sprinkled on it, great heat is produced; the water unites with the earth, forming a *hydrate of lime*. This earth is partially soluble in water, with this singular condition, that it requires less *cold* water to dissolve the same weight of the lime than of hot. This solution, called *lime-water*, possesses alkaline qualities, and is used in many arts; hides are soaked in it, for the purpose of facilitating the removal of the hair, and it is a valuable chemical *test*.

Chloride of Calcium, or chloride of lime, is a most important compound in the arts, from its property of bleaching vegetable tissues; in the bleaching of linen, and in paper-making, the saving of time caused by the use of this substance is incalculable. Linen is first washed in a solution of soda, or

potash, in which it is left to soak for several days, whereby it is freed from the stiffening matter employed in weaving it. Eight leys of potash, of increasing strength, and used hot, are followed by an immersion of the linen in lukewarm water, rendered sour by about a 250th part of its weight of sulphuric acid, and it is then rinsed out in the solution of the chloride. These two last operations are repeated twice, the linen, between the two operations, being exposed to the air, in large meadows, or enclosed places, called *bleaching-grounds*: it is then washed, blued, calendered, and dried.

Calcareous Spar is carbonate of lime, in the purest state in which it is found naturally; it is often as transparent as rock-crystal, but it is usually coloured of various tints by some oxide of iron. Calcareous spar occurs crystallized in nearly 500 forms, all derived from the rhomb, which is its primitive; *macles* are frequent among them; generally, it consists of sixty per cent. of lime, and forty of carbonic acid; when in irregular forms, it may always be distinguished from quartz by its admitting of being scratched by a knife, and by its effervescing when weak nitrous acid is applied to it. *Iceland spar* is this mineral in its purest form, and affords the readiest means of observing the optical *phenomenon* of *double refraction*.

Calcareous spar is found in nearly all the rocks

of every part of the world; it probably owes this universal diffusion to the partial solubility of the earth in water; in this state it filters through the crevices abounding in all strata, and crystallizes again as the water evaporates. When this filtration continues so uninterruptedly as to prevent, by its mechanical action, crystallization from taking place, and yet so gradually as to admit of the solid mineral being deposited from the water, those curious and beautiful concretions called *stalactites* are produced, which ornament in so singular a manner, most natural caverns in rocks or mountains, formed principally of limestone.

In our own country, the county of Derbyshire contains many such caverns, of great beauty and extent; that called the Peak Cavern, near Castleton, is the largest*. The grotto of Antiparos, in the Grecian Archipelago, has been celebrated for ages for its beauty, and the magnitude of its stalactites, but there are many in various parts of the world little inferior to it.

When the stalactites are of sufficient size to admit of being excavated and removed, the mass is called *Oriental alabaster*, and is used for carving into statutes, vases, &c.

* For a description of this cavern, see *Saturday Magazine*, Vol. I., p. 153, and various other caverns are described in Vol. II., p. 73, &c.

Limestone is a generic name for a great variety of rocks; there are two divisions of it. 1st. *Primitive* or *granular* limestone, is so called because it is considered to be of more ancient formation than the other, and because it is crystalline in its texture; it never contains the remains of organized beings, as the secondary limestone does. *Statuary marble*, so valuable in the art of sculpture, as affording a material of which statues, &c., may be cut, equally durable and beautiful, is a primitive limestone; the best, that chiefly employed by the ancients for their finest works, came from the island of Paros, in the Grecian Archipelago, and was hence called *Parian marble.* The artists of modern times, however, employ the Carrara marble of Italy, as being better calculated for smaller works, from its finer and closer grain. That species of statuary marble which is *veined* with bluish or grey streaks traversing it, was termed in ancient times *Pentelican marble;* these veins consist of foreign mixtures, chiefly micaceous, which, decomposing more rapidly from the action of the air, render this species less durable, besides injuring the beauty of the appearance of figures carved in it. Statuary marble is also found in Germany, and the North, as well as in some parts of England.

Common or secondary limestone, contains some *portions of* silex, alumine, oxide of iron, &c. Whole

chains of mountains, as the Alps, Pyrenees, &c., are chiefly composed of it. It abounds in fossil remains, chiefly of marine molluscous animals, of different species and genera to those now existing in the ocean, and also of fishes and other animals of a similar description.

All the ornamental marbles used in architecture, for chimney-pieces, pavement, columns, &c., belong to this division of limestone: these owe their variety and beauty to the imperfect combination of their several ingredients, and also to the abundance of fossil-shells they contain, in some instances constituting nearly the whole mass. The British isles furnish many varieties of these ornamental marbles, of which one quarried in Derbyshire, from its deep and uniform black colour, caused by oxide of iron, is largely employed for making monuments. The Plymouth breakwater is formed of a marble found in the neighbourhood, which, when polished, is prettily variegated. Westmoreland, Devonshire, Durham, Kilkenny, and many other places furnish marbles of great variety and beauty.

The stone used in building, in England, is usually either *Portland-stone*, from the quarries in Portland Island, on the Dorsetshire coast; or *Bath-stone*, so called from its having been used in the erection of that city. Both are varieties of a species of limestone, called *Oolitic*, a term derived from the Greek

name for the roe of a fish, because the texture of the stone somewhat resembles that organ. This limestone is soft when first quarried, but hardens by exposure to the air, a quality which particularly adapts it for the purposes of building. It is an impure kind of carbonate of lime. One variety of this limestone, which belongs to that division of it called the *Lias*, furnishes the stone used in lithography; this is a close-grained sort, free from shells or foreign substances, of a deep cream-colour, and admits of being rubbed to a perfectly smooth and fine surface.

Chalk. This well-known substance is far less abundant than common limestone, but from its forming the principal mass of the hills of those countries in which it occurs, as well as from its being nearest the surface, it attracts more attention. Chalk is of a yellowish or greyish tint, never crystallizes, is soft, light, and opaque; and from its absorbing moisture rapidly, it adheres to the tongue like pipe-clay, though in a less degree. It is nearly pure carbonate of lime, containing, perhaps, about 2 per cent. of alumina.

Chalk is principally confined to England, France and parts of Northern Germany. There are two principal beds or strata of it, the uppermost containing nodules of flints, often lying in such regular layers as to give the appearance of parallel lines

the surface, where a *natural* section of the bed presents its interior to our view: this singular circumstance may be observed in the southern coast of our island, and especially in the Isle of Wight. Chalk also contains organic remains of many kinds, but all of extinct species; it is considered as one of the newest of the solid formations of the crust of the globe.

Chalk is much used for burning into lime, to make mortar and cements for building. This is done in brick-buildings, of a conical form, called *limekilns*. The chalk or limestone is placed in layers with coal, or turf, or wood, according to the country where the process is being carried on; the mass being set on fire, burns for some days, the heat expelling the carbonic acid, and leaving the earth and lime tolerably pure.

Lime thus obtained is called *quicklime*, and must be used early, for it soon absorbs carbonic acid from the air, and is reconverted into limestone. Mortar is made by pouring water on quicklime, which is called *slaking* it, clean river-sand being mixed up well with it; after a time this mixture hardens again, or *sets*: this is caused by the intimate union of the water with the lime, thus forming *hydrate of lime*.

Chalk, when washed, purified, sifted, and formed into masses again, constitutes whiting, employed in

cleaning plate and glass, in making whitewash, &c. Chalk is also used for cutting out moulds, in which lead, tin, and other easily-fused metals may be cast.

Fluate of lime, or more properly *fluoride of calcium*, occurs crystallized, or otherwise; the first kind constitutes what is called, from one of its localities, *Derbyshire-spar*, so ornamental from its colour and transparency. There are seventy varieties of crystals of this mineral, the primitive being an octohedron; it is found in many places, usually in primitive rocks, but its only use is in making ornaments for chimney-pieces.

Sulphate of lime is an abundant mineral salt, presenting itself under various forms, crystallized or otherwise. When compact, one kind is called a variety of *alabaster*, and is used for ornamental purposes, in sculpture and architecture. The stone *Gypsum* is sulphate of lime, and from it is procured that useful preparation called *Plaster of Paris*, which bears the same relation to the natural stone as quicklime does to the carbonate; being obtained in the same way, by burning in a kiln, which dissipates the water contained in the gypsum. When powdered fine, it is employed for *casting* figures modelled from ancient statues, for making *casts of* medals, &c. For these purposes it is mixed *into a paste* with water, and must be used imme-

diately, or else it *sets*, and becomes useless, in consequence of the rapid absorption of the water, and reconversion into a *hydrate*. The coarser-powdered plaster is used for ceilings and walls.

Section 2. Magnesium.

This metal was obtained by Sir Humphry Davy, in a sufficiently separate state to establish its claim to rank among that class of simple minerals. Its oxide, the earth Magnesia, is now well known, though its true nature was only ascertained by Dr. Black in 1755; it had, before that time, been considered as some compound of lime.

Magnesia when pure is, like the others, a white powder, with a slight bitter taste, but no perceptible odour: it changes vegetable blues. It is the least fusible of the earths, and is but little soluble in water.

The powder called *calcined magnesia*, used in medicine as an antacid, or to counteract the effects of too much acidity in the stomach, is prepared by heating the carbonate of the earth to a red heat, till all the acid is dissipated, and the magnesia remains nearly pure.

The peculiar substance called *meerschaum* (sea-foam, literally), of which large bowls for tobacco-pipes are made in Germany, is a carbonate of

magnesia, with small quantities of silex and water, and traces of lime, alumina, and manganese. It is found in different places in the Levant, and is used by the women of those countries as fullers' earth is with us. When first dug, it is lighter than water, porous, and adheres strongly to the tongue.

Epsom salts are a natural sulphate of magnesia, obtained by evaporating the waters of a mineral-spring, near the town of Epsom in Surrey; but, this medicine being in great request, the salt is also prepared artificially.

There is a property possessed by the earth magnesia which is particularly deserving of notice; it is extremely prejudicial to vegetation, so much so that soils in which any of its salts occur are not fertile, and if the earth be present in any quantity they are absolutely barren. In our island there is a range of hills in Nottinghamshire and Yorkshire, consisting of limestone with magnesia; and magnesian-limestone also occurs in the Mendip hills, and in other places. The lime procured from this stone is much esteemed for making cements, as being less liable to decay from the absorption of carbonic acid, than that of the ordinary limestone York Minster is built of it.

Section 3. Strontium.

This metal is as little known as the rest of its class; the time and manner of its discovery is the same. The earth Strontia, which is an oxide, was first obtained from a mineral discovered in the lead-mines of Strontian in Argyleshire, in 1787. It is a grey powder, with a high affinity for water: it is but little known, and is rarely employed, except in making certain fire-works, to which it affords a particular colour.

Section 4. Baryum.

The earth Barytes, an oxide of Baryum, differs in two particulars from the preceding: its specific gravity is much higher than that of the other earths, and it is a most virulent poison. It is a rare earth, being only found in a few minerals, and is not applied to any use.

Section 5. Lithium.

A new alkaline substance was discovered in 1818 by a Swedish chemist of celebrity, while analysing a rare mineral called Petalite; it constitutes but a small part of this and one or two others. The metallic base was detected by Sir H. Davy, but it is altogether uninteresting, except to scientific chemists.

Section 6. Potassium.

This metal was one of the first discovered in 1808, by the late Sir Humphry Davy, as the bases of a set of substances, which, till that time, had been considered as simple elements, namely the *Earths* and *Alkalies*. This discovery is one of the most important in the history of chemistry.

At the temperature of 32° Potassium is hard and brittle, with a crystalline texture; at 50° it becomes malleable, with a lustre like that of polished silver; and at 150° it fuses. Potassium is lighter than water: to preserve it in the metallic form, it must be kept excluded from oxygen, for which gas it has a powerful affinity, uniting with it to form the well-known caustic alkali *potash*, in which the metal was first discovered, and whence it derives its name.

Potassium burns in chlorine with more brilliance than in oxygen; a chloride is the produce of the combustion. It unites with several other metals; its amalgam with mercury possesses the property of dissolving all metals.

The *Potash* of commerce is procured by burning the woody parts of plants that do not grow near the sea: [illegible]hes are repeatedly washed in water, till the [illegible]es off free from any taste; this

water is evaporated in iron pots*, and the alkali is left. The potash is, however, far from pure, though sufficiently so for ordinary purposes; some of the impurities may be got rid of by calcining the alkali: thus improved in quality it constitutes *Pearlash*, and contains from 60 to 84 per cent. of pure carbonate of potash.

The uses of *pearlash* are numerous and important. It constitutes one-sixth in weight of the materials of *flint-glass*, and it is used in soap-making, and in rectifying spirits. Large quantities being thrown into the weak spirits, the water which dilutes these having a stronger affinity for the alkali than it has for the alcohol, the two former unite and subside, leaving the spirit stronger, or purer, floating at top.

When pure Potash, or *Potassa*, is required for chemical experiments, pearlash must be dissolved in twice its weight of hot water, an infusion of fresh-slaked quick-lime is to be added, and the mixture evaporated to dryness. The mass thus obtained must be dissolved in alcohol, and the solution being distilled, by which it is freed again from the spirit, the residuum, when melted and left to cool, is potassa, containing only a small portion of water.

* It was from this mode of preparation that the name potash was derived.

Potash is of endless use in various chemical processes in the arts; many of these are founded on the property which is characteristic of the alkalies —that of forming a *soap* with fixed oils. Potassa is also a powerful flux, which is the cause of its being employed in glass-making as above mentioned.

Nitre, or *Saltpetre*, is *nitrate of potash*, found naturally, either in masses, or in thin irregular crystals; it is white, semi-transparent, and brittle, salt and cold in taste. When thrown on hot coals it burns with a sparkling bright light, and with a crackling noise.

Nitre is found in many localities in most countries, generally in soils derived from the decomposition of granite, the feldspar of which is supposed to furnish the potash, but it is not exactly known whence the nitric acid is derived. India furnishes the principal part of the nitre consumed in England, and the rest of Europe derives a great deal from Hungary. It is not, however, furnished naturally in sufficient abundance to meet the demand, and is therefore manufactured wholesale, in the following manner.

Rubbish, consisting of lime, mortar, plaster, and earth, is mixed up in heaps, under sheds, with *decaying* vegetables and refuse matter, and left to *rot; the* masses being occasionally moistened with

animal fluids, as blood, urine, &c. The azote, disengaged from the corrupting heaps, unites with the oxygen of the atmosphere, and forms nitric acid, which, combining with the potash furnished by the vegetables, produces nitre. The salt is collected, washed, and purified.

The principal consumption of nitre is in the manufacture of gunpowder. This well-known substance is a triple compound of nitre, charcoal, and sulphur, in the proportions of 76, 15, and 9, of each respectively. The goodness of the powder depends on the purity and careful preparation of each of the components, and on their intimate mixture. The charcoal is made by baking the wood in closed iron retorts, till all the foreign matters are expelled; these, as being valuable, are carefully collected in other vessels. The nitre is washed, dissolved, and suffered to re-crystallize to free it from all impurities. Each material is ground, separately, extremely fine, and then mixed up with water into a thick paste; this is forced by machinery through a sort of colander, or sieve, to form it into grains: when nearly dry it is sifted into various degrees of fineness, and each sort is shaken in wooden-hooped barrels, to round off the grains and smooth their surfaces; it is then dried thoroughly, and as it is in this process that the danger of ex-

plosions is incurred, every precaution against such fatal accidents is taken. The powder is spread on shelves round a room, at one end of which an iron plate stove projects into the apartment, the fire being fed from an adjoining one. The stove is covered with copper, to prevent the possibility of a spark being struck from the iron. When dry, the powder is packed in barrels.

During the long war, concluded in 1814, France manufactured the nitre used in her enormous consumption of gunpowder.

The explosive force of gunpowder is owing to the sudden disengagement of a large volume of gas, which instantaneously expands itself. What this gas is, and how it is formed, is not accurately known.

Nitre is used also in salting provisions, to preserve them from decomposition, which it is well calculated to do by its powerful antiseptic qualities.

Mica is a transparent substance of different shades of white, yellow, green, brown, and sometimes black; it crystallizes in hexagonal forms, and is also found massive. It is remarkable for its lamellar structure, which allows of its being split, in one direction, into perfectly smooth shining plates, of almost any degree of thickness, and these plates *are flexible* and elastic. In Russia, Mica is found

in some places, in veins in rocks, in masses of a yard or more in surface, and can be separated into plates $\frac{1}{300000}$ of an inch in thickness. This property makes it valuable on several occasions. In America and Russia it is occasionally used, instead of glass, for windows; and it is employed in small pieces for enclosing minute objects for the microscope. Mica possesses some remarkable optical properties, which render it of frequent use in experiments on the polarization of light.

Mica is a compound of about 50 per cent. silex, 30 of alumina, 8 of potash, 8 of oxide of iron, with traces of manganese, and fluoric acid.

Mica is one of the three minerals which are naturally combined to compose *granite*, and some other primary rocks; the other two components being Quartz and Feldspar. It is the mica which sparkles and gives the greenish hue to some granites. It is also found in masses, filling up the veins of such rocks, and is abundant in some sands, but probably owes its presence in such localities to the decomposition of granite, or gneiss, though these rocks may not now exist in the immediate neighbourhood.

Felspar, or *Feldspath*. There are several varieties of this mineral, though all agree nearly in chemical composition, and all are found both massive and crystallized. Feldspath is lamellar in its structure,

but not in so great a degree as mica; it scratches glass, and is nearly opaque, or at least is only translucent when thin. It is composed of 64 silex, 18 alumine, 13 potash, and 3 of lime, and some oxide of iron.

Common felspar is a generally-diffused mineral, perhaps the most so next to quartz and iron. It is one of the components of Granite, Gneiss, and some other primary rocks. Granite owes its great variety of colour and appearance to the quantity and magnitude of the pieces of felspar it contains.

In some kinds of granite the felspar is in large whitish crystals of irregular forms, in particular instances more than an inch or two long. Since felspar is decomposed by the continued action of the atmosphere, this kind of granite, however beautiful it may be to the eye, is not well adapted for buildings, from its being less durable than the finer-grained species. Waterloo Bridge is, unfortunately, built of such a perishable but beautiful granite. Perhaps the finest specimens of granite for Londoners to examine, are the long slabs with which the foot-path of Westminster Bridge is paved; after a shower of rain has washed them clean, the size and arrangement of the crystals in these blocks is very apparent.

The *Scotch*, or *Aberdeen granite*, with which a great part of the carriage-ways in London are paved, is

close-grained, of a darkish green colour, and so little resembles the kind last mentioned, that few persons, till told, would believe the two to be only varieties of one genus of rocks.

Beautiful and instructive pieces of granite may be picked up by the rational and curious learner, wherever a road is being Macadamized; this being generally done with granite. But, perhaps, the most accessible collection of various granites may be seen in the Egyptian antiquities in the British Museum.

Labrador felspar is a variety remarkable for its beautiful and singular *iridescence*. Besides the locality whence it derives its name, this mineral is found in Norway, Russia, and Siberia.

Talc is a mineral resembling mica in its lamellar structure, but the plates into which it splits are not elastic as those of mica are. Talc is white, yellowish, or of a greenish hue; it is translucent and of a shining lustre, unctuous to the touch, and soft enough to be scratched by the nail. It consists of 61 per cent. of silex, 30 of magnesia, 3 of potash, the rest being variable proportions of oxide of iron and water.

Talc crystallized, is found in primary rocks in the Tyrol, massive: it occurs in similar localities in several countries.

It is employed instead of glass in windows in

some parts of India, and was so also by the Romans. In Bengal plates of it are obtained, varying in size from twelve inches by nine or ten inches square; a mass yielding a dozen such panes, costs two rupees, or about three pounds sterling.

Hydrochlorate of potash, may be noticed here, though not a mineral found in nature. It is prepared by passing a current of chlorine through a solution of pure potash, then boiling and evaporating; the salt obtained is the one in question. It is used for preparing matches for obtaining instantaneous light: the splints of wood are first dipped into sulphur, and then into a paste made of three parts of the hydrochlorate, two of starch, and a small quantity of vermilion. With sulphur, the hydrochlorate of potash forms an explosive compound, used for percussion-caps and fowling-pieces. The Lucifer matches, so justly valued as the easiest mode of obtaining a light, appear to be prepared with this composition; the friction of the sand-paper effecting what the blow with the hammer would do.

Section 7. Sodium.

The history of the discovery of this metal is precisely the same as that of the last. Sodium resembles silver in appearance, and is malleable at

ductile. Like potassium, it is lighter than water; it requires a higher temperature to fuse it than that metal does, and is more permanent. It can be kept in the metallic form for some time, if the air be quite dry, but otherwise when exposed, it soon attracts oxygen, and is reconverted into the alkali *soda*, which is, therefore, one of its oxides.

The compound formed by this metal with chlorine, *chloride of sodium*, is one of those substances which, like oxygen, iron, silex, lime, &c., seem essential to the permanent existence of organized beings, and are consequently universally diffused; this compound is *common salt*.

As an antiseptic its use in preserving animal and vegetable food for our use, for a length of time, during which it would be impossible to preserve them without it, is generally known and acknowledged; but few persons are aware how essential it is to a healthy state of existence, both in man and animals.

In those countries where its abundance renders it cheap enough to be used by all, it is consumed in regular quantities, and its beneficial effects act without being regarded. It is considered as a pleasant and necessary condiment to most kinds of animal and vegetable food, and that is all; but there are districts not so fortunate in this respect, and there a craving is felt for it which induces the

greatest exertions and hardships to be endured, in order to procure it.

Mungo Park, in his travels in Africa, witnessed this, and uses the following strong expressions on the subject: "It would appear strange to an European to see a child suck a piece of rock-salt as if it were sugar: this, however, I have frequently seen; although the poorer class of inhabitants can so rarely indulge in this precious article, that to say, a 'man eats salt with his provisions,' is the same as saying he is a rich man. I have suffered great inconvenience myself from the scarcity of this article; the long use of vegetable food creates so painful a longing for salt that no words can sufficiently describe it."

Captains Lewis and Clarke, in their journey up the Missouri, when looking for a proper spot to pass the winter, were guided in their choice principally by the facility the place might afford for making salt. They fixed on a spot, after much deliberation, and their salt-pans on the sea-side were fifteen miles distant, which journey some of the party had to perform at stated intervals, their routes lying through woods and morasses; the weather all the time cold and rainy: but till they could procure a constant supply of this necessary, they were reduced to considerable privation, and were compelled to feed on poor fish and roots,

which produced disorders among them seriously affecting their health. They were all this time surrounded by elks, deer, and fine game, which they could shoot in sufficient quantities to supply themselves with good wholesome food, but it was impossible to keep the flesh for two days for want of salt.

But, as will be presently shown, it is the want of activity, intelligence, or of civilization, among the inhabitants of the countries where this privation is felt, that subject them to these privations, rather than any deficiency in the supply of this necessary.

Animals feel the same want: in the woods of North America there are small salt-springs, called *licks*, which are watched by the hunters from the certainty of game coming to drink at them, or to *lick* the saline earth, if the spring be dry. Farmers in England know, that to mix a certain quantity of salt with sheep's fodder is a preventative against the rot, or murrain, to which those animals are liable; and even birds, as pigeons, require salt when in confinement. About a million of tons annually is consumed by animals in this country alone.

An able physician having discovered, that salt was a specific for a certain class of fevers of the intermittent kind, has satisfactorily accounted for

this effect, on the soundest and most philosophical principles. In general, an adult may be considered as consuming from five to six ounces of salt a week, where it is abundant.

Salt has been, consequently, generally diffused over the globe, in lavish abundance, by the wisdom and benevolence of the Creator. It occurs in two forms, either as a solid mineral, or in solution, in the waters of the ocean, and of lakes and springs in inland districts.

Rock-salt forms strata and beds in different localities. A series of them extends quite across the continent of North America: there are salt-mines in Mexico, which furnish anually nearly 1,800,000 bushels. There is a solid rock of salt in Catalonia in Spain, nearly three miles in circumference, and between four and five hundred feet high. It is made into candlesticks, cups, vessels, and toys, by the peasants. In France, Germany, Hungary, and Poland, there are extensive rocks and strata of salt. The island of Ormuz, in the Persian Gulf, is one rock of salt. In Africa it is equally abundant, and forms a plain in Abyssinia which is four days' journey in extent. The salt-mine of Wieliezka is celebrated by the recitals of the travellers who have visited it. It is entered by six shafts, of four or five yards in diameter, and sixty to seventy deep. The mine is worked to a depth of upwards of

yards, its bottom being fifty yards below the level of the sea. The works in the mine are astonishing; there is a stable, apartments, a chapel, &c., all the furniture of which is made of salt. This mine furnishes 120,000 quintals of salt annually. There is a similar mine at Northwich in Cheshire, (see *Saturday Magazine*, vol. i. p. 152,) which furnishes 156,000 tons annually.

The inhabitants of countries on the sea-coast, in warm climates, derive their supply of salt from the waters of the ocean. Shallow pits or *pans* are dug near the shore, and lined with clay, the water is admitted, or flows, into these at high tides; the heat of the sun evaporates most of the water, and the rest is pumped off, leaving a crust of salt lining the bottom of the pan: this is broken up and piled in heaps under sheds to drain, which requires from two to three years to do effectually, during that time a liquid containing foreign matter in solution running off from the salt. A great many pits are required in such salt-works, because it takes a considerable time to allow of a sufficient quantity of salt being deposited.

In colder climates, where the heat of the sun is not sufficient to produce the same effects, sea-water is boiled in large pans till it is evaporated, leaving the salt; the pans are replenished several times before the crust of salt is removed.

In Russia, sea-water is let into shallow pits, and as it is a property of water not to freeze when it holds salt in solution, except at a low temperature, the ice formed on these pits consists of nearly pure water, consequently the salt contained in the whole quantity of liquid is left in the water that remains uncongealed, which thus being saturated, a small portion of fuel suffices to evaporate the fluid, leaving the salt in crystals.

The waters of the ocean contain $\frac{1}{30}$ of their bulk of salt in solution; but the proportion varies in different seas.

Pure salt should not become moist by exposure to the air; its liquefaction, in such circumstances, is owning to foreign ingredients, which have a strong affinity for water.

Lakes of salt-water exist in many parts of the globe. There are several in Southern Africa; one, near the Cape of Good Hope, is three miles in circumference, the whole bed of the lake is a mass of crystallized salt, of unknown thickness: near the shore it is from four to five inches, and is broken up by pickaxes by the colonists, who resort to it for a supply.

In the Mahratta country in India, there is a salt-water lake nearly sixteen miles square, about thirty feet deep in the middle: there is a rocky island in the centre, in the middle

is a natural well of perfectly *fresh* water. The mode of obtaining the salt does not differ materially from that practised elsewhere.

But the salt-springs furnish a large portion of this mineral, which is required in most countries of Europe; in our own, especially, those at Droitwich, in Cheshire, are remarkably abundant, furnishing upwards of 16,000 tons of salt annually. The water is pumped up by steam-engines into large iron pans, to be evaporated by artificial heat.

In France, the mode of proceeding to obtain the salt from the brine-springs is ingenious and economical: the water is raised by pumps to the top of a lofty building, from which it is suffered to fall through a labyrinth, composed of branches of trees; this causes the water to divide into fine drops like rain, while a strong current of air passing through the building, by evaporating a considerable portion of the pure water, leaves that which reaches the ground much more strong or concentrated. The water from the wells only contains 1½ per cent. of its weight of salt, while by this contrivance it is increased to 18 per cent. This strong brine is then evaporated in the usual way.

The brine-springs of America are stronger than those of England: the strongest, however, in any

country, yield only one-fourth of their weight in salt.

The uses of salt, besides as a condiment to food, are numerous; it is employed in glass-making, in enamelling and glazing of earthenware, in the preparation of several chemical substances, as corrosive sublimate, sal-ammoniac, &c.; it is also, on account of the chlorine which it contains, used in bleaching, and also in iron-works, and for various other useful purposes. About a pound of salt is mixed with a bushel of flour to make bread. It is a powerful manure, and when not too abundantly used, it stimulates vegetation; for which purpose it is best applied mixed with soot, in quantities of from five to fifteen bushels of salt per acre. Grain is also steeped in brine before it is sown, as a preservative against certain diseases.

Natron is a carbonate of soda found in different forms, crystallized and massive, the principal supply being derived from lakes in Egypt and Hungary. The waters hold this salt, as well as common salt, in solution, and it is deposited on the margins, crystallized by evaporation.

Natron is used in medicine, and in the arts, as in the manufacture of soap, glass-making, &c.

Glauber Salt is a sulphate of soda, found dissolved in the waters of many lakes and springs, or crystallized, in various localities; the ashes of

some plants also contain it. The natural salt is not very pure, for the purposes of medicine it is prepared artificially.

Common salt, being decomposed by sulphuric acid, is converted into Glauber salt. The soda having a greater affinity for the acid than the metal has for the chlorine, by mixing the artificial salt with chalk and carbon, the pure soda is obtained; by calcination and washing, the liquid left is hydrochloric acid. By this simple process three important products are obtained.

Soda, however, is more commonly and more plentifully obtained by burning several species of marine plants, especially *salsola kali*, and *salsola soda*, and some *fuci*. A considerable quantity is imported from Spain under the name of *Barilla*, because, in the Spanish language, that is the name of the plant employed.

Borax is a salt of soda formed of the alkali, with boracic acid. It is prepared artificially by purifying the natural *borate of soda*, a mineral which is found in Thibet, where it is held in solution in the waters of a lake, which also contains common salt. This lake, from its great elevation above the level of the sea, is frozen during a great part of the year.

The borax in its rough state, obtained from the East, is called *Tincal*, and is purified after its im-

portation into Europe. Borax is also prepared by dissolving pure soda in boracid acid, obtained from lakes in Tuscany. Borax is an important article in the arts, as a flux in the reduction of many metals, especially in assaying; it is also used in enamelling, &c.

The two alkaline oxides, potash and soda, are commonly called *fixed alkalies*, from their usually presenting themselves in a solid form. There is another alkali which has been long known to chemists, to which the name *volatile alkali* was given, from its being a gas when in its state of purity. *Ammonia*, as it is also called, is a triple compound, formed of *Azote* and *Hydrochloric acid*, which is a compound of hydrogen and chlorine. Hence it appears, though essentially an alkali, ammonia is not, like the two others, a metallic oxide. It is mentioned here, because it enters into the composition of some salts, much employed in the arts.

Sal-ammoniac is found in various states, often in volcanic districts, in cracks in lava, also in coal-mines, and dissolved in the waters of some lakes in Tuscany, &c. Its primitive crystal is the cube; it is prepared artificially, to meet the demand for it, but the processes are too complicated to be described in this work.

Sal-ammoniac is used in cleaning the surfaces of copper vessels to prepare them for tinning, (see p. 184,) or for soldering, and for many other purposes. In 1824 and 1825, one hundred and fourteen tons of this salt were exported from Calcutta. It was formerly brought to this country from Egypt, where it was procured by submitting the soot of camels' dung to distillation in closed vessels; it is now manufactured by subliming a mixture of sulphate of ammonia with chloride of sodium (common salt.)

The waste water used in purifying coal-gas for illumination is mixed with impure sulphuric acid and distilled; the product is *sulphate of ammonia*. To this, powdered chalk (carbonate of lime) is added, a double decomposition takes place, and *sulphate of lime* and *carbonate of ammonia* are obtained. This last-named salt is used for the preparation of smelling-salts, which owe their powerful pungent odour to the volatile alkali: it is also largely used by pastry-cooks, mixed up with the flour, to make their pastry light; the carbonic acid disengaged during the baking, swells the dough and leaves it porous, while the alkali being driven off by the heat, no unpleasant taste is imparted to the cookery.

INDEX.

	Page
Affinity, attraction of	8
Agate	37
Agents, imponderable	2
—— ponderable	3
Alabaster	217, 222
Alum	210
—— roch	211
—— Roman	211
Aluminum	204
Amalgams	79
Amber	29
Amethyst	35
Antimonial Wine	197
Antimony	196
Arsenic	151
Attractions of Gravity and Affinity.	8
Avanturine	34
Bath-stone	219
Baryum	225
Bell Metal	127
Beryl	213
Bismuth	119
Bitumen	28
Black Chalk	42
Blende	199
Blue Vitriol	145
—— Prussian	160
Borax	243
Brass	124
Bronze	126
Cadmium	148
Calamine	200
Calcareous Spar	216
Calcium	214
—— Chloride of	215
Calomel	79
Carbon	23
Carnelian	37
Cat's-eye	35
Cerium	203
Chalcedony	36
Chalk, black	42
—— red	43
Charcoal	23
Chromium	202
Chrysoprase and Heliotrope	37
Cinnabar	79
Clay	39
—— Slate	40
—— Pipe	42
—— Potters'	42
Coal	28
Cobalt	148
Coin, Gold	69
—— Silver	114
Columbium	203
Combinations of Simple Substances	21
—— of Metals, &c.	43
Copper	123
—— Mines	128
—— alloys of	124
Corrosive Sublimate	79
Corundum	207
Crystals, Primitive	18
—— Rock	33
Crystallization	16
Cupellation	10
Diamond	23
Elementary Principles, or Simple Substances	2
Emerald	213
Emery	207
—— Paper	208
Epsom Salts	224
Feldspar	231
Flake White	121
Flint	33
Fullers'-earth	41
Fulminating Powder	89
—— Gold	76
—— Mercury	89
—— Platinum	56
—— Silver	119
Fusible Metal	93
Galena	95
Garnet	36

	Page
ling	70
uber Salts	242
cinum	213
d	57
- Leaf	72
nite	232
vity and Affinity, attractions of	8
vity, Specific, explanation of	13
en Vitriol	159
sum	222
cinth	212
onderable Agents	2
rganized Matter	1
ium	203
i	155
- Meteoric	161
per	38
	29
ten, or Tin Plates	185
d	89
- Black, or Plumbago	27
- White	90
- Red	91
- Sheet	100
- Rolled	101
- Pipes	101
- Sugar of	92
e	214
iarge	90
ium	225
ar Caustic	118
achite	43
iganese	201
ble	218
— Parian	218
— Pentelican	218
— Black	219
— Statuary	218
sicot	90
erial Bodies, division of into natural kingdoms	1
rschaum	223
cury	78
al, Bell	126
— Speculum	183
allic Ores	43
Metals, properties of	4
——— names of	6
Meteoric Iron	161
Mica	230
Mineral Oil, or Naphtha	27
Mines, general account of	44
——— of America	109
——— of Hungary	60
——— Carniola	84
——— Cornwall	128, 194
——— Bohemia	107
——— Sweden	134, 164
Mining	44
Minium	91
Mirrors, silvering	81
Molybdenum	181
Naphtha, or Mineral Oil	27
Native Metals, (see respective Metals.)	
Natron	242
Nickel	154
Nitre	228
Ochre, Red	163
Oil, Mineral, or Naphtha	27
Onyx and Sardonyx	36
Opal	35
Ores, Metallic, (see the respective Metals)	43
Oriental Ruby	206
Orpiment	151
Osmium	203
Palladium	102
Pearlash	227
Petroleum	27
Pewter	183
Phosphorus	32
Pinchbeck	125
Pipe-clay	42
Plating	115
Platinum	54
Plumbago, or Black Lead	27
Ponderable Agents	3
Portland Stone	219
Potash	226
Potassium	226
Pot-metal	127
Potters'-clay	42
Powder, Blue	130
——— Fulminating	89

	Page
Prase	34
Precious Metals	65
Primitive Crystals	18
Prince Rupert's Metal	125
Properties of the Metals	4
Prussian Blue	160
Pyrites, Copper	128
—— Iron	157
—— Magnetic	157
Quartz	33
Realgar	151
Reddle	163
Rhodium	203
Rock Crystal	33
Ruby, Oriental	206
—— Spinelle	209
—— Balas	210
Sal-ammoniac	244
Salt, common	235
—— Springs	241
—— Mines	238
Sand	36
Sapphire	206
Sardonyx and Onyx	36
Silex	33
Silicon	33
Silver	103
—— Coin	104
Simple Substances, or Elementary Principles	2
Slate, Clay	40
Smalt	149
Soda	235
Sodium, Soda	235
Solder,	183
Specific Gravity, explanation of	13
Speculum Metal	183
Steel	
Stream Tin Works	
Strontium	
Substances, simple, or E tary Principles	
Sulphur	
Talc	
Tellurium	
Thorinum	
Tin	
— Mines	
— Works	
— Plates, or Latten	
— Ores	
— Putty	
Tinning	
Titanium	
Topaz	
Tripoli	
Tungsten	
Turquoise	
Tutenag	
Uranium	
Vanadium	
Verdigris	
Verditer	
Vermilion	
Vitriol, Blue	
—— Green	
—— White	
White Lead	
Whiting	
Yttrium	
Zaffre	
Zinc	
Zirconium	

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